AIDS TO SANITARY SCIENCE

SECOND EDITION

ALLAN — FARRAR

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BAILLIÈRE, TINDALL & COX.

Alfred Rogers.
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AIDS

TO

SANITARY SCIENCE

FOR THE USE OF CANDIDATES FOR PUBLIC HEALTH QUALIFICATIONS

BY

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Second Edition

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PREFACE TO THE SECOND EDITION.

THE kind reception accorded to the first edition of this work encourages the Editor to hope that a second edition will not be less successful in achieving the object indicated by the title, that of affording 'Aids' to students preparing for Sanitary Science Examinations. Many additions have been made to our knowledge of hygiene during the past decade. Advantage has accordingly been taken of the demand for a second edition to bring these 'Aids' up to date in conformity with modern knowledge and the requirements of students. The increase in the size of the work thus occasioned has made it necessary to omit the questions formerly incorporated in the Appendix. Acknowledgments are due to various authors whose works have been laid under contribution, but in a volume of this scope, which is frankly a compilation for the use of students, it has been found impracticable to acknowledge the source of each and every excerpt.

R. A. F.

CHISWICK, W.,
December, 1902.

PREFACE TO THE FIRST EDITION

THE range of subjects embraced in the term 'Hygiene' is so extensive and varied that it is a matter of difficulty for the busy practitioner, who is a candidate for a Public Health qualification, to bring the mass of knowledge into an easily accessible condition. My intention here is to present the numerous facts in such a form that the student of the subject may readily refresh his memory without having to read through matters of a controversial or explanatory nature, the insertion of which is, of course, necessary in a text-book.

I have taken as my guide the classical work of the late Dr. Parkes, as edited by Professor de Chaumont, but I have supplemented the information there obtainable by that provided by the writings of specialists, so as to present as far as possible a résumé of the latest additions to our knowledge in each division of the subject.

It is impossible within the limits of these 'Aids' to attempt any synopsis of the various Acts of Parliament relating to Public Health, but I have taken the opportunity, when it offered, to draw attention to any Act or By-law which may bear on the subject of the text.

Experience gained as a teacher has shown me that difficulty is not infrequently encountered in dealing with

statistics and mathematical calculations generally; with a view, therefore, of making these more easily understood, I have added examples of questions (taken from examination papers), so as to exhibit the methods by which they may be solved.

F. J. A.

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AIDS TO SANITARY SCIENCE

CHAPTER I.

INTRODUCTORY.

THE University of Dublin was the first to institute, in 1871, an examination in public health. but it was not until 1886 (Medical Act, Section 21) that the General Medical Council was empowered to register such diplomas.

Up to 1888 no special qualification had been required of medical men desirous of becoming medical officers of health; but in that year an important step was taken by Parliament by the provision in the Local Government Act that—except where the Local Government Board, for reasons brought to their notice, may see fit in particular cases specially to allow—no person hereafter shall be appointed the medical officer of health of any county, or county district, or combination of county districts, or the deputy of any such officer, unless he is legally qualified for the practice of medicine, surgery, and midwifery.

Since January 1, 1892, no person can be appointed the medical officer of health of any county, or of any such district or combination of districts, as contained, according to the last published census for the time being, a population of 50,000 or more inhabitants unless he is qualified as above mentioned, and also is registered in the *Medical Register* as the holder of a diploma in sanitary science, public health, or State medicine, under Section 21 of the Medical Act, 1886, or had been, during three consecutive years preceding the year 1892, a medical officer of a district, or combination of districts, with a population according to the last published census of not less than 20,000, or has, before the passing of this Act

been for not less than three years a medical officer or inspector of the Local Government Board.

A similar provision has been incorporated in the Local Government (Scotland) Act, 1889.

I. The General Medical Council, having regard to the terms of Section 18 of the Local Government Act, 1888, and of Section 54 of the Local Government (Scotland) Act, 1889, and observing that under those sections special privilege is to be accorded to the holders of these diplomas, has declared, with regard to its own future action under Section 21 of the Medical Act, 1886, that it will not consider diplomas to 'deserve recognition in the *Medical Register*' unless they have been granted under such conditions of education and examination as to insure (in the judgment of the Council) the possession of a distinctively high proficiency, scientific and practical, in all branches of study which concern the public health; and the Council, in forming its judgment on such conditions of education and examination, will, on and after June 3, 1902, expect the following rules to have been observed :

1. A period of not less than twelve months shall have elapsed between the attainment of a registrable qualification in medicine, surgery, and midwifery and the admission of the candidate to any examination or any part thereof for a diploma in sanitary science, public health, or State medicine.

2. Every candidate shall have produced evidence that, after obtaining a registrable qualification, he has during six months received practical instruction in a laboratory or laboratories, British or foreign, approved by the licensing body granting the diploma, in which chemistry, bacteriology, and the pathology of the diseases of animals transmissible to men are taught.

3. Every candidate shall have produced evidence that, after obtaining a registrable qualification, he has during six months (of which at least three months shall be distinct and separate from the period of laboratory instruction required under Rule 2) been diligently engaged in acquiring a practical knowledge of the duties—routine and special—of public health administration, under the supervision of—

(*a*) In England and Wales, the medical officer of

health of a county, or of a single sanitary district having a population of not fewer than 50,000, or a medical officer of health devoting his whole time to public health work ; or

(*b*) In Scotland, a medical officer of health of a county or counties, or of one or more sanitary districts having a population of not fewer than 30,000 ; or

(*c*) In Ireland, a medical superintendent officer of health of a district or districts having a population of not fewer than 30,000; or

(*d*) A medical officer of health who is also a teacher in the department of public health of a recognised medical school.

*** The certificate of an assistant medical officer of health of a county or of a single sanitary district having a population of not fewer than 50,000 may be accepted as evidence under Rule 3, provided the medical officer of health of the county or district in question permits the assistant officer to give the necessary instruction and to issue certificates.

*** Provided that the period of six months may be reduced to a period of three months (which shall be distinct and separate from the period of laboratory instruction required under Rule 2) in the case of any candidate who produces evidence that, after obtaining a registrable qualification, he has during three months attended a course or courses of instruction in sanitary law, sanitary engineering, vital statistics, and other subjects bearing on public health administration, given by a teacher or teachers in the department of public health of a recognised medical school.

4. Every candidate shall have produced evidence that, after obtaining a registrable qualification, he has attended during three months the practice of a hospital for infectious diseases at which opportunities are afforded for the study of methods of administration.

*** Methods of administration shall include the methods of dealing with patients at their admission and discharge, as well as in the wards, and the medical superintendence of the hospital generally.

5. The examination shall have been conducted by examiners specially qualified; it shall have extended over not less than four days, one of which shall have been devoted to practical work in a laboratory, and one to practical examination in, and reporting on, subjects which fall within the special outdoor duties of a medical officer of health.

> *** The rules as to study shall not apply to medical practitioners registered, or entitled to be registered, on or before January 1, 1890.

6. The Council shall from time to time appoint an inspector or inspectors of examinations in public health, with special instructions to report to the Council whether the examining of each licensing body does or does not afford evidence, on the part of candidates passing such examination, of a distinctively high proficiency, scientific and practical, in each and all of the branches of study which concern the public health.

The examination is usually divided into two parts. Part I. comprises physics and chemistry, the principles of chemistry, and methods of analysis, with special reference to analyses of air, water, and food; application of the microscope; bacteriology; the laws of heat and the principles of pneumatics, hydrostatics, and hydraulics, with especial reference to ventilation, water-supply, and drainage; construction of dwellings, disposal of sewage and refuse, and sanitary engineering in general; statistical methods. Candidates will be expected to understand the application of the general laws of chemistry to such cases as occur in the practice of an officer of health, and to know the methods of analysis, and be able to interpret correctly the results of professional analysts.

Part II. comprises laws of the realm relating to public health; origin, propagation, pathology, recognition, and prevention of epidemic and infectious diseases; effects of overcrowding, vitiated air, impure water, and bad or insufficient food; unhealthy occupations and the diseases to which they give rise; water-supply and drainage in reference to health; distribution of diseases within the United Kingdom, and effects of soil, season, and climate.

Examinations are made by written papers, orally and practically.

The subjects embraced in the two parts of the examination of necessity overlap one another to some extent.

It is most desirable that students preparing for examinations in sanitary science should embrace every opportunity of gaining practical experience, and they should visit and inspect water-works, sewage farms, and other methods of sewage disposal, hospitals, gasworks, factories, sanitary exhibitions, etc.

The importance of a thoroughly practical acquaintance with the administration of public health is emphasized by the General Medical Council, who recommend that the medical officer of health should be required to certify not only that the student has had sufficient opportunities for acquiring a thorough knowledge in practical sanitary work, but that to his knowledge the pupil has honestly taken advantage of these opportunities.

As a guide to what should be read, the lists of books which are issued by the various examining bodies may be consulted. It it well also to procure copies of the papers set at previous examinations.

A sanitary inspector appointed in London after January 1, 1895, must hold the certificate of such a body as the Local Government Board may from time to time approve (Public Health (London) Act, 1891, Section 108). A special examination board was formed in 1899 in order to provide such certificate, the possession of which is now compulsory.

In the rest of England a certificate is not required by law, but local authorities frequently require candidates for the position of inspector of nuisances to hold this or a similar certificate.

CHAPTER II.

WATER-SUPPLY.

THE subject of the supply of water to towns may be considered under the three headings of:

1. Quantity of water supplied per head.
2. Mode of collection, storage, and distribution.
3. Composition, at source and throughout the district supplied, and the possibility of contamination at any point.

Quantity.—The amount actually supplied in this country varies considerably. The general average supplied by the London water companies is 35 gallons per head daily.

The following are some of the gross amounts supplied for all purposes to different towns:

	Gallons per Head Daily.
Manchester	24
Edinburgh	36
Glasgow	52
Dublin	35
Paris	53
Berlin	22
St. Petersburg	49
Rome	220

These differences are, doubtless, due rather to waste than to variations in the amount actually used. By the employment of a staff of inspectors and the use of water-waste meters and 'detectors,' great economy may be effected. Thus, in Liverpool the average amount supplied daily was reduced from 33 to 23 gallons and in Exeter from 75 to 12 gallons by the introduction of Deacon's water-waste detectors, together with efficient inspection, without any restrictions being placed on the consumers.

The quantity required varies according to the needs of the locality. If water must be limited, 4 gallons for each adult *per diem* is the least amount allowable. For personal and domestic use, 12 gallons per head is the usual minimum; with baths, water-closets, and waste, 25 gallons; and this is the quantity that experience shows to be necessary for keeping the sewers in proper working order.

The following table gives the quantities required on an average for various purposes:

	Gallons per Head Daily.
Domestic use:	
Drinking (besides which 30 to 50 ounces is taken in bread, meat, etc.) ...	0·33
Cooking	0·75
Ablution, including sponge-bath, 2½ galls.	5·00
Share of utensil and house washing ...	3·00
Share of clothes washing	3·00
Water-closets	6·00
General bath (weekly about 30 gallons)	4·00
Unavoidable waste	3·00
	25·08
Town and trade purposes:	
Washing streets, courts, etc., extinguishing fires, supplying fountains, etc., allowance for trade and for animals in non-manufacturing towns	5·00
Allowance for exceptional manufactures	5·00
	10·00

Making a total of 35·08 gallons.

By order of the Secretary of State for War, each officer, man, and woman occupying quarters receives 20 gallons and each child 10 gallons daily. In hot countries a large amount is required for bathing and washing.

Hospital patients require from 40 to 50 gallons daily. Many hospitals use far larger amounts than these, but in such cases there is probably much unchecked waste.

Collection of Water.—The sources of supply may be classified under two main heads:

(*a*) *Surface supply*, from rain, snow, brooks, rivers, lakes, surface-fed springs and shallow wells, etc.

(*b*) Supply from *deep subterranean sources*, as from springs cropping out at the foot of mountain ranges, from natural reservoirs, from artesian and other deep wells.

Rain-water in this country, on account of atmospheric impurities, is seldom stored except for external use. The uncertainty of rainfall also tells against its use. One gallon of rain contains on an average eight cubic inches of gases, the oxygen being in larger proportion (32 per cent.) than in atmospheric air; the carbonic acid amounts to only about 2 per cent. of the mixed gases. In the neighbourhood of human dwellings the rain contains soot, sulphuric acid, tarry and other matters derived from the combustion of coal, and ammoniacal salts, nitrates, albuminous and other organic matters derived from decomposing animal and vegetable substances, and the exhalations from the bodies of men and animals, together with various débris and innumerable micro-organisms, bacteria, micrococci, moulds, pollen, etc.

When properly collected, however, rain-water can be stored and utilized for all domestic purposes. When it is decided to collect rain-water from the roofs of houses, a 'rain-water separator' should be employed. This consists essentially of a self-acting canter, balanced upon a pivot, which cants and directs into a waste-pipe the first lot of water, which has washed the dirt from the roof. Since it never contains more than a trace of lime-salts in solution, it is exceedingly soft, and well adapted for washing. By proper filtration it can be rendered potable. Rain-water, especially in certain districts where manufacturing towns abound, frequently contains a distinct trace of sulphuric acid, and then acts freely on various metals. It is not safe, therefore, to store it in lead, zinc, iron, or galvanized iron tanks. For small cisterns earthenware may be used. If slate tanks are used, the joints being made with white or red lead, the angles where the lead is exposed should be filled with cement. Brick storage tanks should be well puddled outside with clay, and lined inside with Portland cement.

Ice-water is heavy and non-aërated. Water in freezing loses part of its saline contents, but it should be re-

membered that it is not rendered thereby free from bacteria.

Snow often contains much organic matter, and should never be collected from the neighbourhood of dwellings to melt for use.

Dew is used sometimes in waterless regions and on board ship.

The *rainfall* varies greatly in different parts of the world with the latitude, altitude, distance from the sea, direction of the prevailing winds, extent of forest, and position with regard to mountain ranges. It also varies greatly at certain seasons. In certain deserts—Sahara, Gobi, Central Australia, etc.—rain eeldom or never falls. Near the equator the rainfall is almost perpetual. In the Khasia Hills in Assam the average annual rainfall is over 400 inches.

The average annual rainfall in England is 30 inches, and varies from 22 to 23 inches in the eastern counties, to an average of over 75 inches in the mountainous districts of Cumberland, Wales, and Devonshire. In the Stye Pass in the Cumberland hills about 200 inches of rain falls annually. A quantity is lost by evaporation or by sinking into the ground. This varies from one-half to seven-eighths, according to the season of the year and the porosity of the soil.

The amount of water given by rain is calculated from (1) amount of rainfall, and (2) the area of the receiving surface.

The former is ascertained by a rain-gauge. One inch of rainfall corresponds to nearly $4\frac{3}{4}$ gallons per square yard, or 22,620 gallons per square acre, equal to 101 tons of weight on each square acre (4,840 square yards $=1$ square acre; 640 square acres $=1$ square mile); then area in square feet $\times$ 144 (to bring to square inches), $\times$ rainfall $=$ total amount (in cubic inches) on area in given time.

Product (in cubic inches) $\div 277{\cdot}274$, or $\times\ 0{\cdot}003607 =$ number of gallons.

One inch of rain $= 4{\cdot}673$ gallons on every square yard, equal to 101 tons of weight on each square acre.

One cubic foot of water $= 6{\cdot}2355$ gallons ($6\frac{1}{4}$).

One gallon of water weighs 10 lb.

In estimating the amount of rain that can be collected from a sloping roof, take the area as that of a transverse section of the house, including walls and eaves—that is, take the area of the ground covered by the roof. If the average rainfall be 20 inches, it would only give two gallons per day to each person if collected only from roofs of houses in towns, assuming each house to have an average roof area of 60 square feet to each individual.

In estimating *annual yield of water* from rainfall, or the yield at any one time, it is necessary to know: (1) the greatest, (2) the least, (3) the average annual rainfall, (4) the period of the year when it falls, and (5) the length of the rainless season.

The greatest is generally about one-third more and the least one-third less than the average. A safe basis is to take the average of the three driest years. This will generally be about five-sixths of the average annual rainfall. The rainfall varies in amount often in places near together.

River-water is rain derived directly from the atmosphere, and indirectly through part of the earth. The impurities vary according to part of country drained, the quality being worse after heavy rains.

Spring and *well waters* are influenced by the strata through which the water passes; thus it may be either good pure water, mineral water, or nothing less than diluted sewage. Two classes of wells are recognised—viz., the shallow and the deep. The shallow well does not extend below an impermeable stratum, and is therefore readily contaminated from the surface of the ground. The deep well derives its supply from below an impermeable stratum, either by being sunk at a point where the substratum crops out, or by boring through the clay or other impermeable layer, when the term 'artesian' is applied to the well.

The configuration of the country should be considered in regard to water-supply. Springs at the foot of hills are permanent; in flat districts the supply is doubtful, unless derived from a great depth; in limestone regions springs from subterranean reservoirs are permanent; in chalk districts springs are few unless below level of country generally; similarly where sandstone obtains,

but when there are deep wells large reservoirs must have been tapped. Water from granitic and trap formations is variable unless from lochs.

To determine Yield of Springs, Streams, etc.—The water of a spring may be received into a large vessel of known capacity, and the rate of filling timed.

To determine Yield of a Small Watercourse.—(1) Dam up the course and convey water through a channel of known dimensions, such as a wooden trough of certain length, and in which the depth of water is known; the time taken by a float in passing from one end to the other is measured.

(2) Or a sluice of known size is formed, and the difference of the water above and below is measured—discharge = area of opening of sluice $\times 5\sqrt{\text{head of water in feet}}$.

(3) Or a weir is formed, the waste-board having a thin edge and a free overfall.

(4) Or this plan, which is sufficiently accurate, may be adopted: A part of the stream is selected where it is free from eddies, and pretty uniform in breadth and depth for about twelve or fifteen yards, or a part may be cut so. Drop in a chip of wood and note the length of time it takes to float the given distance. This will be the surface velocity, which is greater than the mean velocity; then four-fifths of the surface velocity × area of cross section = yield of stream per second.

It should be determined at different times of the day and on several occasions.

The following tables are given by the Rivers Pollution Commissioners:

1. In respect of wholesomeness, palatability, and general fitness for drinking and cooking purposes:

Wholesome.	1. Spring-water ...	Very palatable.
	2. Deep well-water ...	
	3. Upland surface-water	Moderately palatable.
Suspicious.	4. Stored rain-water ...	
	5. Surface-water from cultivated land ...	Palatable.
Dangerous.	6. River-water, to which sewage gains access	
	7. Shallow water ...	

2. Classified according to softness with regard to washing, etc. :

1. Rain-water (the softest).
2. Upland surface-water.
3. Surface-water from cultivated land.
4. Polluted river-water.
5. Spring-water.
6. Deep-well water.
7. Shallow-well water (the hardest).

The purest water comes from the granitic, millstone grit, and hard oolite formations ; also from the chalk, but it is hard. Water from the selenitic, with calcium sulphate, is unwholesome ; from alluvial it is very impure ; and near the sea wells are sometimes brackish.

Storage of Water.—To determine the amount of water which should be stored, it is necessary to know, when dependent on rainfall, (1) amount used, and (2) ease of replenishing. This latter depends upon the rainfall and upon the area of catchment.

With a catchment area large in proportion to population, and with a fairly distributed rainfall, the necessary storage space will be less than in a district where there are long droughts to be provided for, and where, the catchment area being small, it is essential that loss by escape of water during heavy floods should be minimized by providing large reservoirs.

The average loss by overflow of storm water may be taken at about 10 per cent. of total fall. The average proportion of rainfall available for storage at about six-tenths of the whole.

Reservoirs in rainy districts may contain 120 days' supply ; in drier districts 200 days' supply.

Hawksley's formula for storage is $D = \frac{1000}{\sqrt{F}}$,

D being number of days' supply to be stored, F mean annual rainfall (five-sixths of average). Storage capacity may vary from 25,000 to 50,000 cubic feet per acre of catchment area.

To calculate Size of Reservoir.—Number of gallons

required daily for whole population $\div$ 6·23, to bring to cubic feet, and $\times$ number of days the supply is to last = size of reservoir in cubic feet.

All reservoirs require to be frequently cleaned; they should be covered in and ventilated; in form deep rather than extended, so as to lessen evaporation and secure coolness. If too large to be covered in, a smaller covered one with a filter between should be provided, containing three days' supply.

Wells should have a good stone coping to prevent entrance of surface washings during rain. To prevent subsoil soakings it is necessary to brick round the well for some distance down.

If subsoil-water be raised by means of an iron conduit pipe sunk in a water-bearing stratum, preferably sand, rather than by sinking a well, many chances of contamination are avoided, and the water is to a greater or less extent filtered through the various layers of soil before it is drawn to the surface.

Large reservoirs are made watertight by a core of clay puddle; the inner slope is protected by a pitching of dressed stones, the outer by a covering of grass sods; the summit of the embankment should be 3 to 10 feet higher than the water level; the top is covered with broken stones; no trees or shrubs must grow on it, and care must be taken to prevent the possibility of rats burrowing into it; an overflow weir is provided to permit of discharge of flood-water from the drainage area, and is supplemented by a by-wash, which diverts the foul flood-water of the streams supplying the reservoir; there is a cleansing-pipe at the lowest level; the discharge-pipe bends upwards, is perforated with holes at different heights, and has guards to prevent entrance of stones, wood, etc. Certain plants, as protococcus and chara, give off oxygen, and may be allowed in reservoirs; but duck-weed (lemna and pistia), and all dead vegetable matter should be removed.

Distribution of Water.—Two systems are in vogue for the distribution of water in towns; these are called the intermittent and the constant methods of supply.

The *intermittent* necessitates storage in cisterns in the house for from one to three days.

Disadvantages.—1. With an *intermittent* supply the main pipes lie constantly exposed to the risk of *insuction of polluting matter*, fluid or gaseous; moreover, the intermittent charging of the service-pipes favours corrosion which, in turn, causes turbidity of the water.

2. *In case of fire*, with an intermittent service, a supply of water cannot be insured without the intervention of a turncock.

3. *Cisterns*, however well designed and however often cleansed, are *open to sources of contamination*, from which the mains, under a constant supply, are free.

4. Cisterns are less easily guarded against *frost* than communication pipes coming off the mains.

5. Even though water stored in cisterns be not specifically polluted, water taken from them is less cool and potable in hot weather (when a supply of good water is of vital importance not only to public health, but to public morals) than water taken direct from the mains.

The *intermittent* system, which is condemned by nearly all authorities on hygiene, has been defended on the score of economy; but with a system of periodical inspection of fittings, and the use of water-waste-preventing meters, the substitution of a constant for an intermittent supply has even been found to effect a considerable economy of water.

The storage of water in houses must be regarded as a necessary evil, but it is perhaps desirable that small cisterns should be provided in connection with a constant supply. These should hold from 30 to 50 gallons, or sufficient for one day's use.

On either system the water is conducted in large pipes of earthenware or iron, which may be either wrought, or cast, or galvanized, or lined with concrete, or covered with vitreous glaze (De Lavenant), or with Dr. Angus Smith's bituminous varnish, or subjected to Barff's process (*i.e.*, by being exposed while hot to super-heated steam a coating of magnetic oxide (Fe_3O_4) is produced).

Iron is best for the large pipes, and is necessary also for the small on the constant system on account of the pressure. With intermittent supply, pipes are made of iron, lead, tin, zinc, copper, earthenware, gutta percha, artificial stone, etc. Copper tinned and block tin pipes

are good, but are said to be eaten into if nitrates are present in the water.

Water should be laid on to every house, and to each floor in the houses of the poorer classes. An insufficient supply leads to deficient washing of persons, clothes, houses, yards, streets, and drains, and produces a lowered state of health among the population.

Size of Pipes.—The *greatest hourly* demand for water is about double the average hourly demand ; hence main conduits must be correspondingly large.

For calculating the size of pipes and delivery of water these formulæ are useful (Eytelwein) :

D = Diameter of pipe in inches.
H = Head of water in feet.
L = Length of pipe in feet.
W = *Cubic feet* of water discharged per minute.

Then $W = 4{\cdot}71\sqrt{\frac{D^5 H}{L}}$. $D = 0{\cdot}538\sqrt[5]{\frac{L W^2}{H}}$

A head of water is made up of a head of pressure and a head of elevation (Rankine).

1. Head of pressure = the intensity of the pressure exerted by the particle expressed in feet of water.
2. Head of elevation = the actual height of the particle above some fixed or datum level.

A foot of water at 52·3° F. = 62·4 pounds on a square foot (atmospheric pressure is not usually regarded).

Admission of Impurities to Water.—Impure water-supply may be due to impurities of (1) mineral, (2) vegetable, or (3) animal nature, of which the last, especially when they are fæcal matter, are the worst.

They may gain admission to the water at the gather ground, in transit, or during storage.

In Transit.—Water in streams and open conduits may be rendered impure by surface-washings, leaves, sewage, etc. The Rivers Pollution Commissioners divide such impurities into—

(*a*) *Sewage.*—All liquid and solid excreta, house and waste water; all impurities coming from dwellings. This is usually organic matter, and undergoes change into (1) ammonia, then into (2) nitrites, and finally to (3) nitrates.

(*b*) *Manufacturing.*—All manufacturing refuse, as from dye and bleach works, tanneries, paper-making, etc.

If conveyed in pipes, water may be contaminated by lead and other metals; by leakage from drains and sewers and gas-pipes; by impurities of the soil finding a way into pipes through some faulty joint.

During Storage.—Wells and tanks are liable to have the water rendered impure by surface-washings, soakings, absorption of foul air by uncovered surface of water, leakage from pipes. A well drains an extent of ground like an inverted cone, the size of the area depending on the kind of soil; the radius of the cone = at least four times the depth of the well.

Fissures of considerable size often exist in chalk formations, down which sewage may pass and travel long distances underground, to the danger of water-supplies. Oolitic and sandstone formations are often similarly fissured. Solutions of common salt or lithia may be poured into places suspected of having communication with the source of a water-supply, and the water of the same subsequently examined.

Mineral matters in excess in water:

Hard waters produce dyspepsia, constipation, and sometimes diarrhœa; goitre and cretinism are associated with magnesian limestone formation, but not everywhere, for magnesian limestone occurs in Scotland, Ireland, and Scandinavia, without presence of these diseases. It has been suggested that the connection depends not merely on the mineral, but on a super-added organic factor as yet undiscovered. Calculi and diseases of bones are alleged to be caused by drinking such water.

Iron in quantity may produce headache and dyspepsia.

Brackish water from wells near the sea may set up diarrhœa.

Sulphurous acid in water is injurious to health.

Action of Water on Lead.—Those waters *act most* on lead which are the softest* and most highly oxygenated, especially those containing—

(*a*) Much oxygen.
(*b*) Carbonic acid in excess. only
(*c*) Organic matter, animal or vegetable.
(*d*) Nitrites (especially ammonium nitrite; lead nitrite is formed, then lead carbonate, and nitrous acid is set free to act on another portion of lead; it exists in most distilled water).
(*e*) Nitrates (modified or arrested by the presence of carbonates or sulphates).
(*f*) Chlorides.
(*g*) Free sulphuric acid derived from iron pyrites or from imperfect combustion, as stored rain-water in the neighbourhood of large towns.
(*h*) Vegetable acids from fruits, vegetables, peat, etc.
(*i*) Pieces of loose mortar or cement.

At the line of contact of the water and air in the pipes a crust is formed, and this is liable to be broken off.

Solution of the lead is also produced by galvanic action, which is set up by the juxtaposition of other metals, and by bending lead pipes against the grain, exposing the structure.

Lead is also taken up by water from zinc pipes. The deposit in lead pipes consists of carbonates, phosphates, and sulphates of lead, calcium, and magnesium (if the water contained these salts), and lead chloride. This deposit may be broken off and dissolved.

Those waters have the *least action* on lead which contain—

(*a*) Carbonic acid (carbonate of lead is formed, and acts as a protecting coating to the pipes, and prevents further action, but an excess of carbonic acid would dissolve it).
(*b*) Calcium carbonate, phosphate (great protective power), and sulphate (not so much).
(*c*) Magnesian salts and alkaline phosphates.
(*d*) Silica.

* Under 6° 'chalk' a water is reckoned as soft, above 12° the hardness becomes marked.

To prevent the taking up of lead by water various suggestions have been made, the most useful being: protecting the pipes by McDougal's bituminous coating, varnishing with coal-tar, coating with lead sulphide (Schwartz) by boiling in sodium sulphide. Block-tin is sometimes recommended as a lining, but the safest method is the adoption of iron pipes protected by Barff's or Angus Smith's method, glass-lined or galvanized.

The addition of quicklime (2 grains to the gallon) has been used to counteract acidity, and water passed through silica is found to have less action on lead than it had previously.

Amount of Lead allowable in Drinking-Water.—Any quantity over $\frac{1}{20}$ grain should be considered dangerous; some people are affected by less ($\frac{1}{100}$ grain). Wanklyn adopts $\frac{1}{10}$ grain per gallon as justifying rejection of a water.

Impurities of *animal* or *vegetable* origin—rhizopoda, infusoria, hydrozoa, rotifera, scolendæ, entomostraceæ, and insecta—are found in water, together with fungi, algæ, diatomaceæ, and many other organisms. For the most part these are believed to be harmless in themselves, though infusoria and fungi indicate the presence of organic pollution.

The following are some of the Entozoa, etc., which may be conveyed by water:

1 Ova of *Tænia solium*, *T. mediocanellata*, and other Tæniæ.

2 *T. echinococcus* (embryo develops into hydatid cysts).

3 *T. bothriocephalus latus* (both eggs and embryo).

4 *Distoma hepaticum* (eggs developed in water).

5 *Ascaris lumbricoides*, or round worm.

6 *Oxyuris vermicularis*, or thread worm.

7 *Dochmius duodenalis* (*Strongylus D.* or *Anchylostomum D.* produces a form of pernicious anæmia, anchylostomiasis).

8 *Filaria dracunculus* or *Medinensis* (guinea-worm).

9 *F. sanguinis hominis.*—The embryo is taken into mosquito's stomach with blood of persons infected with this parasite; it begins developing and is then transferred to water and so back to man.

10 *Bilharzia hæmatobia* (producing hæmaturia).

Leeches sometimes attach themselves to the throat and larynx, and produce bleeding and emaciation.

Vegetable matters in water are in solution or suspension. Water brown from peat is not objectionable ; it should not be stored in lead cisterns, and should be filtered before it is used ; it has been known to cause diarrhœa. Water from marshes should be avoided ; it may cause diarrhœa, dysentery, or ague.

Microbes, micrococci, bacteria, bacilli, spirilla, etc., are always present in natural waters, even the purest, but their number is greatest in impure waters. Their number is influenced by temperature, exposure to sunshine, and the volume of the water. Most of these microbes are harmless, and their mere numbers afford only a very rough indication of the quality of the water, for they multiply rapidly in water after collection, and are constantly recruited by aerial microbes. Thus, a sample of water from a deep chalk well contained seven microbes per cubic centimetre when fresh, twenty-one after standing for a day at 20° C., and 495,000 after standing three days (Frankland). Pathogenic microbes may, however, be conveyed by water and give rise to various diseases.

The following diseases are frequently, if not generally, 'water-borne': cholera, enteric fever, dysentery, diarrhœa.

An epidemic of diarrhœa in a community is referable to air, water, or food :

1. If a number of persons are suddenly taken ill, it is probably one of the two last ; and if spread over many families, it is almost certainly due to the water.
2. Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, may be due to water.
3. A very sudden and localized outbreak of either enteric fever or cholera points to the water supply.

Thus, in regard to *cholera* in 1886, the evacuations of the first two patients in the eastern district of London were received into the river Lea, from which soakage took place into the uncovered reservoirs of the East

London Water Company ; the epidemic which broke out was confined to the district supplied by the company.

The same applies to other water-borne diseases.

Bacteriological analysis may, if well timed, detect even in the minute samples examined either the actual germs of these diseases or, far more probably, other microbes, which, like *B. coli communis* or *B. enteritidis sporogenes*, serve to prove dangerous excremental pollution. The comma bacillus thrives for months in sewage, but soon perishes in pure water. The same is true of *B. anthracis*, but the spores retain their vitality even in distilled water. A bacillus known as *Beggiatoa alba*, characterized by the presence of grains of sulphur in its substance, is found in marsh-water and in sulphur springs, in water containing sewage, and also in the effluents from certain works, especially sugar factories and tanyards. It reduces sulphates and will grow in water in which sulphates abound (Whitelegge).

The general health is lowered by impure water. In the East ulcers and boils, such as the affection variously known, according to the locality, as Delhi, Aleppo, or Bagdad, etc., boil, have been attributed to contaminated water.

The Purification of Water.

Nature purifies water from vegetable and animal matter by decomposition and oxidation, aided by subsidence and filtration through porous strata, by dilution, and by the agency of fish or other animal or vegetable life.

Artificially water may be purified by—

1. Distillation.
2. Boiling.
3. Subsidence, aided by the addition of various ingredients.
4. Filtration.
5. Exposure to air in divided currents.

1 **Distillation** will insure pure water if properly carried out. Distilled water requires aeration to render it palatable. Efficient filtration will aerate water.

2. **Boiling** removes the *temporary* hardness of water by expelling carbonic acid from the soluble calcic bicarbonate

and causing precipitation of the insoluble calcic carbonate. Thus:

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O.$$

Water is hard or soft according to the amount of solid residue which it contains. Of the total hardness, the *temporary* hardness is the amount of calcium carbonate which can be thrown down by boiling and expulsion of carbonic acid; the remainder, consisting of calcium sulphate and chloride and magnesain salts, constitutes the *permanent* or fixed hardness.

Boiling also drives off sulphuretted hydrogen, and lessens the amount of organic matter and iron.

Bacilli are killed by boiling, but their spores are more resistant. Boiling on two or three successive occasions is necessary, in order to get rid of the bacilli developing from spores, and thoroughly 'sterilize' the water.

3. **Subsidence.**—Allowing water to stand for some time favours subsidence, not only of heavy particles, but, to some extent, of organisms generally. This is, however, increased by the addition of various precipitating agents, as:

Lime (*Clark's* process) combines with the carbonic acid of the calcic bicarbonate, an insoluble calcic carbonate being precipitated, and carrying with it suspended matter and some dissolved organic matter and iron. Organisms are almost entirely removed. It does not affect sulphates and chlorides of calcium, or magnesium salts, unless caustic soda be added with the lime. Hard water may be softened upon the large scale in reservoirs by adding one ounce of quicklime per 100 gallons for every degree of temporary hardness. The *Porter-Clark* process is a modification of Clark's. Instead of waiting for slow subsidence, which takes ten or twelve hours, the precipitated calcic carbonate is removed rapidly by filtration through cloth under pressure.

Aluminous salts act well if calcium carbonate be present; a sulphate is formed, and with a bulky hydrated alum precipitate floating matters are carried down.

Potassium or sodium permanganate removes by oxidation the offensive odour of impure water kept in casks, and of hydrogen sulphide; suspended matters are carried down by the manganic oxide precipitate.

Perchloride of iron purifies turbid waters from clay, etc.

Immersion or boiling in the water of certain vegetable bodies, especially such as contain *tannin*. Tea, kino, bitter almonds, *strychnos potatorum*, etc., have been used.

Charring the inside of casks is useful.

Agitation with small fragments of coke, spongy iron, or scrap iron purifies from organisms (Frankland).

To sum up, impurities are most readily removed thus:

Organic matter by { Distillation, boiling, precipitation with alum, permanganates, tannin, and by agitation with coke, etc.

Carbonate of lime by boiling and addition of lime.

Iron by boiling, lime, and in part by charcoal.

Micro-organisms by boiling.

A combination of alum, lime, and sodium carbonate removes the temporary and even reduces the permanent hardness somewhat.

4. **Filtration** is used on a large scale in connection with water-supplies to towns, etc. After the water has stood for some time in a settling tank to allow the heavier suspended matters to subside, it is led to filters composed of sand and gravel, and through these it passes either by ascent or descent. The component parts vary according to the quality of the water, but the following is an example of the manner in which a filter is made:

Beginning at the bottom, there are 1 to 2 feet 6 inches of rough stones, getting smaller towards the top, 3 to 6 inches of gravel, $\frac{1}{2}$ to $\frac{3}{4}$ inch of shells, 3 to 6 inches of pea gravel, and $1\frac{1}{2}$ feet to $4\frac{1}{2}$ feet of sand. The top layer should be a fine silicious sand, never less than 1 foot in thickness, which can be removed and washed when it becomes impervious. For water containing much organic matter, as at Wakefield, it was found that a

second filtration through a bed consisting of 4 inches of gravel at bottom, 15 inches of Spencer's magnetic carbide, and 9 to 15 inches of fine sand at top, turned out bright and clear water. The pressure of water is kept low, the depth not being more than 1 to 2 feet. The water must not pass through the filters at a rapid rate. This varies with the quality of the water from 300 to 800 gallons per square yard per twenty-four hours. In the latter case, of course, the water must be comparatively pure to begin with.

In efficiently acting filters, organisms may be removed to the extent of 99 per cent. of their total number in the water. This is due to the gradual formation in the upper layers of the filter of a slimy substance, composed of growing micro-organisms. After scraping of the filter for cleansing purposes, the efficiency of the filter is somewhat diminished, and during the first few days the effluent should not be passed into the general supply. Care should be taken to prevent freezing of the surface, as, should this occur, pathogenic bacteria might pass into the effluent.

Sand filtration, when carefully pursued, offers a most remarkable and obstinate barrier to the passage of microbes, and there is every justification for presuming that if disease organisms are at any time present in the raw, untreated water, they will be similarly retained (Frankland). Sand filters, however, can only lay claim to relative, not to absolute efficiency. The effect of filtration upon dissolved matters in water is slight, and there is an increase in the nitrogen as nitrates and nitrites, probably from the action of the microbes in the filter.

The same method may be applied to wells by filling them to the highest water-level with gravel, and over the gravel with sand to the very top, an iron pipe being first sunk into the gravel.

Small and Domestic Filters.—These are of two kinds: (1) those which aim at acting chemically on the water as well as straining off the grosser suspended impurities; (2) those which act mechanically, having pores sufficiently fine to strain off all micro-organisms.

1. Of the first type are various filters, in which the filtering medium is some preparation of carbon, charcoal

(animal or vegetable), silicated or manganous carbon, 'carbo calcis,' etc.; or of iron, magnetic carbide of iron, spongy iron, etc.

Filters of this type strain off grosser suspended impurities, and render water more palatable by aerating it. The most effective of them, when fairly new, slowly oxidize organic matter held in solution and lessen hardness, together with the nitrites and ammonia. Nitrates are increased. The Bischoff spongy iron filter claims to remove lead.

Such filters are, however, frequently bought and sold with the belief that they remove disease germs. It cannot be too strongly insisted on that they are wholly ineffective for this purpose. Professor Sims-Woodhead has shown that such filters not only do not diminish, but, after the first few days, actually increase, and that enormously, the number of micro-organisms in water. The filtering medium also requires to be frequently renewed or cleansed to maintain its chemical efficiency.

2. To obtain water bacteriologically pure filters of the second type are required, which have no effect on the chemical constituents in solution, but have pores so fine as to strain off all micro-organisms.

Of this class are the Pasteur-Chamberland filter of unglazed porcelain, and the Berkefeld filter of infusorial earth. These will remove practically all organisms, and are used in bacteriological laboratories for obtaining sterile water. Organisms, together with all suspended matter, are deposited on the outside of the 'candles,' and are readily removed by brushing with a 'loofah,' or bristle-brush. It has been shown, however, that even in these filters bacteria will in course of time grow through the pores of the medium. To obviate this they should occasionally be sterilized by heat. To obtain rapid filtration with these filters pressure is requisite. In dealing with muddy water, preliminary filtration to screen off the grosser impurities is to be recommended. It was found in the Transvaal campaign that the Pasteur filters were choked every few minutes by the muddy water of the Modder River. On a large scale 'batteries' of Chamberland filters may be employed to purify public water-supplies.

Examination of Water.

Water is examined by physical, chemical, and biological methods.

Collection of Samples.—The quantity should not be less than half a gallon. A 'Winchester quart' glass-stoppered bottle is the most convenient bottle to use. It must be thoroughly cleansed before use, and before being charged it should be rinsed out with some of the same kind of water as that which is to be analyzed. When charged the bottle should not be quite full, and should have the stopper or clean new cork tied over with a piece of clean linen, calico, leather, bladder, or indiarubber, and the string sealed against the bottle.

Samples should be kept in a cool, dark place, and examined within forty-eight hours if possible.

Full information should be sent with the sample concerning the water, its surroundings, place, time, and method of collection, note of any disease attributable to its use, etc.

Good drinking water should have the following physical characteristics :

Colour.—When seen through a depth of one or two feet it should have a bluish or grayish appearance ; if of peaty origin, it may be brownish.

Clearness.—Should be transparent.

Brilliancy or *lustre* should be well marked. It is a guide to the aeration of the water, and the comparative terms *nil*, dull, vitreous, and adamantine are used to denote the amount of lustre.

Taste.—There should be none, except what is due to the gases dissolved.

Sediment.—There should be no sediment or suspended matter except what rough filtration will remove.

Smell.—None, either cold or warmed, or on addition of KOH.

Chemical Constituents of Usable Water.—The total solids should not exceed 30 or 40 grains per gallon.

Chlorine should in general be under 3 grains per gallon or 4 parts per 100,000 in good water ; but in the neighbourhood of sea-water, or in deep wells from salt-bearing

strata, a higher amount need not excite suspicion. It is not easy to fix a standard of the amount of chlorine permissible. To form a correct judgment it is necessary to take into consideration the average character of the waters in the district. Where not otherwise accounted for, an excess of chlorine should excite suspicion of sewage contamination.

Nitrates 'may be found in pure water from deep wells in the chalk, but as a rule are due to oxidation of organic matter of animal origin. Even if accompanied by only a small proportion of organic matter, nitrates in water from a source open to suspicion must be regarded as oxidized filth, which may at any time be followed by unoxidized filth' (Whitelegge). A trace of nitrates not exceeding $\bar{N} = 0{\cdot}35$ per 100,000 would not suffice to condemn a water otherwise pure.

Nitrites must be considered as pointing to sewage contamination, and their presence should condemn the water. They indicate more recent and therefore more dangerous contamination than nitrates.

Albuminoid Ammonia.—Water giving 0·00 parts per million may be passed as organically pure, even though much free ammonia and chlorides be present. Thus, many deep-well waters contain ammonia and nitrates, but they contain no organic matters, showing at once that there has been no previous pollution by sewage. Water may be passed as good if free ammonia be absent, or very small in amount, with as much albuminoid ammonia as 0·1 per million (·007 grains per gallon). Water is suspicious with much free ammonia along with more than ·05 parts per million of albuminoid ammonia.

Much organic impurity is probably of vegetable origin if chlorine be less than 1 grain per gallon.

Free ammonia should be under ·0050 parts per 100,000 (·0035 grains per gallon). 'Free ammonia' is often derived from urea. Urea is only found in water very recently contaminated. for it speedily becomes carbonate of ammonia.

Nitrogen compounds expressed as 'organic nitrogen' should not be more than ·023 parts in 100,000.

Frankland records all the nitrogen present, whether in the form of nitrates, nitrites, or ammonia, under the head

of 'previous sewage contamination,' recent or remote. The nitrogen is sometimes stated in terms of nitric acid (HNO_3).

Oxygen absorbed ought not to exceed 0·1 per 100,000 within fifteen minutes for organic matter alone—that is, after deducting any that may be absorbed by nitrous acid, if present. A mean of many comparative analyses indicates that 3·35 parts of oxygen absorbed per 100,000 is the equivalent of one part per 100,000 of organic carbon by Frankland's process (Notter and Firth). For upland surface and peaty waters a much larger amount of organic matter may be safely passed.

Hardness total should be under 12° (Clark).

Hardness fixed should be under 4° (Clark).*

Phosphoric acid as phosphates, if in large quantities, indicates sewage impregnation, unless derived from phosphoric strata (rare). Traces may be allowed.

Sulphuric acid as sulphates should be under three parts per 100,000 (2 grains per gallon).

Iron—traces are permissible—should be under two-tenths of a grain per gallon.

Sulphides of Hydrogen or Alkalies.—Presence of these should condemn any water.

Microscopic Characters (600 to 1,200 diameters).—Mineral matter ; vegetable forms with endochrome ; large animal forms, but no organic débris as muscular fibre, epithelium, or other animal structures, spiral vegetable fibres, wheaten or potato starch cells, cotton or linen fibres, or other evidence of house refuse, and no fungi or bacteria, ova of parasites, etc. should be found. (Sewage matters have a dark reddish-brown or reddish colour, and are in globular masses, while decomposing vegetable matter is flatter and more spreading. Mineral particles are angular, clay and marl round, smooth globules, unaffected by acids ; chalk smooth and crystalline, soluble with effervescence in acids; iron peroxide, reddish-brown, amorphous masses, soluble in HCl, and turning deep blue with ferrocyanide of potassium.)

Biological Characters.—Microbes in drinking-water should not exceed 100 per c.c. Pathogenic organisms

* Very soft waters, such as upland surface-water, are apt to produce fragility of bones in children, owing to deficiency of lime-salts.

are, of course, inadmissible. The presence of organisms liquefying gelatine should excite suspicion.

Biological Examination of Water.—Special care must be taken in the collection of samples to avoid contamination of the water, or of the flasks or bottles to be used, which must be previously sterilized. Bacteria multiply very rapidly in water, and the examination should, if possible, be made immediately after collection. When it is not possible to make the cultivations on the spot, Professor Frankland recommends that the bottles or hermetically sealed tubes be packed in a box surrounded with ice, as at the freezing-point of water practically no increase of the microbes will take place in the sample. The examination is carried out as follows: A tubeful of sterilized, nutrient gelatine, liquefied by heat, is inseminated with a known quantity of the water—0·1 c.c. to 0·5 c.c., or even 1 c.c., according to the sample—poured into a Petri's culture-dish, and incubated at a constant temperature for a few days. When the germs have developed into colonies, they may be counted (conveniently by means of a Wolffhugel's plate), and their characteristics noted. The colonies can be separately examined. To isolate pathogenic organisms which may be present, subcultures must be made in suitable media. Instead of plate-cultures, the method of roll-cultures is sometimes employed.

The bacteria may also be collected by passing the water through a Chamberland or Berkefeld filter, washing the sediment off by means of a sterilized brush, and then cultivating in the ordinary way.

Water is examined chemically:

1. Qualitatively.
2. Quantitatively.

Qualitative Analysis.—Note first the presence or absence of the various physical characteristics already mentioned.

Use litmus and turmeric papers, and note reaction. If acidity disappears on boiling, it is due to carbonic acid. If alkalinity disappears on boiling, it is due to ammonia. If permanently alkaline, to sodium carbonate.

It is advisable to concentrate a portion of the water

to be examined to one-fiftieth in the porcelain dish, otherwise important ingredients, as lead, zinc, or nitrates in minute quantities, might be overlooked.

Reagents and the necessary appliances are provided in Public Health Examinations (anything required is usually supplied on demand). Dip the platinum wires into acid and hold them in flame, to cleanse from soda before making the flame test. Make sure that all vessels, pipettes, etc., supplied are clean.

If the following tables be worked through systematically, nothing will be missed, and the specimens of water will be easily examined in the alloted time.

State the various steps taken in making analyses, even if there are no results. Sometimes distilled water forms one of the samples given at examinations.

Table for the Detection of the Base in Solution.

To 100 c.c. of the water in a white porcelain dish add a drop of ammonium sulphide (NH_4HS) and stir. A black coloration implies the presence of iron, copper, or lead.

Fe. If due to iron, it will be discharged on the addition of a few drops of HCl.

Cu. Copper may be recognised by the appearance of a reddish-brown colour or precipitate on the addition of potassium ferrocyanide (K_4FeCy_6) to a fresh portion of water; or by a light-blue precipitate with ammonia, soluble in excess of the reagent, forming a dark-blue solution.

Pb. Lead gives a yellow precipitate with either potassium iodide or potassium chromate (K_2CrO_4) solutions.

Zn. Arsenic, barium, manganese, chromium, and zinc sometimes find their way into drinking-water, from chemical and other works or receptacles, and the last-named may be dissolved from galvanized iron pipes, but, with the exception of zinc, need not be looked for as a rule.

Zn. **Al.** The tests for zinc, however, may be made at the same time as those for alum. They may be differentiated by the following tests:

Reagent.	Zn.	Al.
NH_4HO	White ppt. soluble in excess.	White ppt. insoluble in excess.
K_4FeCy_6	White ppt.	No ppt.
KOH (a few drops).	White ppt. soluble in excess; not re-ppt. on adding NH_4Cl.	White ppt. (gelatinous) soluble in excess; re-ppt. on adding NH_4Cl freely.
Evaporate to dryness on platinum foil and add drop of nitrate of cobalt.	Green colour.	Blue colour.

(Reinsch's and Marsh's tests for **As** and **Sb** should be known, but time is not given in the practical examination to perform the various processes. Add the HCl to water in a test-tube containing piece of **Cu** wire heat = gray deposit on wire; treat the copper in a Marsh's apparatus, when the deadly vapour of arsenuretted or antimoniuretted hydrogen will pass off. Light it, and hold a piece of cold porcelain in the flame; a black deposit will be produced. Pour some solution of chlorinated lime on the deposit. If soluble, it is arsenic; insoluble, antimony. If another piece of the copper wire be dried and heated in a dry test-tube, the deposit will sublime and condense on the sides of the tube in octahedral crystals if arsenic, in amorphous form if antimony.)

Ca. Lime-salts may be detected by a white precipitate formed with ammonium oxalate, soluble in nitric acid. Only a turbidity is formed up to 15 grains per gallon. A platinum wire dipped in water containing lime and held in a flame produces a dull, brick-red colour. The flame test may also be applied to sodium salts (yellow), lithium (crimson),

and potassium (pale violet; best seen through two pieces of blue glass).

Mg. Magnesia cannot readily be tested for at an examination, as it requires twenty-four hours for the production of the triple phosphate crystals, calcium salts being precipitated and removed, and solutions of sodium phosphate and ammonium chloride added with excess of ammonia.

NH_4. A few drops of Nessler's solution gives a brownish-yellow discoloration, or a brownish precipitate, according to the amount of ammonia present (*vide* Quantitative Analysis).

Table for the Detection of the Acid in Solution.

Sulphates.—Having eliminated any lead, add barium chloride solution ($BaCl_2$), when a white precipitate will have formed, insoluble in strong HCl. With quantities under 2 grains per gallon, a haze will form after standing.

Chlorides.—Nitrate of silver ($AgNO_3$) solution gives a white, precipitate, insoluble in dilute nitric acid, but soluble in dilute ammonia.

The candidate may readily estimate the amount of chlorides in the water in the manner given below.

Nitrates.—Pure H_2SO_4 and a crystal of brucia added to some concentrated water cause a pink coloration, or with a solution of brucia a pink and yellow zone; or, add to the water an equal bulk H_2SO_4, wait till cold, then float on surface $FeSO_4$. A dark olive zone results.

Nitrites.—Add KI and fresh solution of starch, acidulate with dilute H_2SO_4, immediate blue colour results; or, solution of metaphenylene diamine added gives a yellow colour (let it stand twenty minutes). Brownish gas comes off on adding H_2SO_4. Ilosvay's solution of sulphanilic acid and naphthylamine gives a rose tint if any trace of nitrites be present.

Carbonates.—Evaporate some water to dryness and add HCl, effervescence occurs. Pass the colourless, odourless gas into lime-water, a white precipitate

occurs. Carbonates give an immediate precipitate with magnesium sulphate. Bicarbonates do not.

Phosphates.—Concentrate and add $NH_4Cl + NH_4HO + MgSO_4$, white precipitate occurs. If solution of phosphate be dilute, the precipitate requires some time to form. Or, add ammon. molybdate solution with dilute HNO_3 and boil, yellow precipitate forms on standing.

Sulphides.—Add a few drops dilute HCl, H_2S is evolved, and may be recognised by its odour. Moist acetate of lead paper held over tube slightly warmed turns black. With nitroprusside of sodium solution a violet or purple colour will show sulphides to be alkaline. No colour, but precipitate with lead, means H_2S uncombined.

Organic Matter.—Rapid decoloration of a potassium permanganate solution indicates the presence of recent animal contamination in the absence of iron, nitrites, or sulphides; or, chloride of gold solution may be employed (*vide infra*).

In stating the results of analysis, each metal and acid radical may be stated separately, or each acid may be given as combined with the base for which it has most affinity. The chief salts will be found to be calcium carbonate and sodium chloride.

Quantitative Analysis.—*Total solids* are determined by evaporation of a known quantity of water (usually 70 c.c.*) to dryness at a moderate heat in a platinum dish, the weight of which has been previously ascertained; the residue which adheres to the dish after evaporation is then weighed with the dish. The difference will, of course, represent the solids of the water. The residue consists largely, as a rule, of carbonate of lime, which will effervesce on the addition of a drop of hydrochloric acid.

* Seventy cubic centimetres of water weighs 70,000 milligrammes, and, as 1 gallon weighs 70,000 grains, 70 c.c. is a sort of miniature gallon wherein the milligramme corresponds to the grain. If we know the number of milligrammes of residue which 70 c.c. leave, we know also the number of grains of solids in a gallon of water (Wanklyn). To obtain parts per 100,000, multiply grains per gallon by 10 and divide by 7.

The dried solids are now incinerated, the volatile matters are driven off, and the fixed solids remain. The volatile portion represents destructible organic matter, ammoniacal salts, water, and carbonic acid. The volatile substances are so uncertain in composition that little importance is now attached to the incineration test. Unless the water be from a peat land, the solids should blacken very little on ignition.

Chlorine is determined thus : Into a given quantity of water (to which has been added a small quantity of yellow chromate of potassium), silver nitrate (4·79 grammes to a litre of water) is dropped and stirred up after each addition. The red silver chromate will disappear so long as any chlorine is present. Stop when the red tint becomes permanent. One c.c. of the silver nitrate solution used represents 1 milligramme of chlorine. Neither the water nor the nitrate of silver solution must be acid, else the silver chromate will be dissolved.

Hardness is ascertained by Clark's soap test. Rationale : When an alkaline oleate is mixed with pure water, a lather is formed ; but if lime, magnesia, iron, alumina, etc., be present, more of the oleate in varying quantities will be required to form a lather.

To determine Total Hardness.—Seventy c.c. of the water are put in a stoppered bottle, and standard soap solution added (not more than 1 c.c. at a time), the bottle being well shaken after each addition ; when a thin, beady lather is produced over the whole surface, and remains permanent for five minutes, the process is complete.

From the number of cubic centimetres (or 'measures') used, deduct one, the amount necessary to give a lather with 70 c.c. of pure water. Then, as 1 c.c. corresponds to 1 milligramme of calcium carbonate, the number of measures used is the number of milligrammes of calcium carbonate in the 70 c.c., or the number of grains per gallon. The result may be expressed as parts per 100,000, or as degrees of Clark, in which a degree represents a grain of calcium carbonate per gallon. If expressed metrically, the result may be converted into degrees (Clark) by multiplying by 0·7.

Permanent or Fixed Hardness.—Boil the water and

use soap test again. The result will represent the permanent hardness, due to calcium sulphate and chloride and magnesian salts. The difference in the results of the two tests represents the—

Temporary or Removable Hardness.—It is this which causes the 'fur' in boilers. Each degree of hardness implies the waste of about 12 lb. of the best hard soap for each 10,000 gallons used in washing. The soap test has also been used to determine approximately the amounts of lime, magnesia, free carbonic acid, and sulphuric acid in water. Thus :

Lime.—Take total hardness ; then precipitate lime by ammonium oxalate and test again. The difference will be due to lime.

Magnesia.—Boil water from which lime has been eliminated ; the result of the soap test will represent magnesia.

Carbonic acid exists in water as carbonates, bicarbonates, or free.

The *earthy carbonates* may be estimated by adding methyl orange as an indicator, and titrating with a standard mineral acid. The yellow colour remains until the carbonates are decomposed and free acid is present, when a red colour appears.

Free Carbonic Acid.—Eliminate lime as above ; test ; then water freed from lime is to be boiled and tested. The difference will represent the carbonic acid driven off. Or, free carbonic acid may be estimated by the addition of phenolphthalein, and dropping in a $\frac{N}{20}$ solution of Na_2Co_3 till a pink colour appears. Each c.c. of the soda solution represents 11 milligrammes of free carbonic acid.

Sulphuric Acid is determined by the use of a solution of nitrate of barium. The hardness (supposing no SO_4 present) would be equal to the original hardness of the water, plus that of the baryta solution ; but SO_4 being present, barium sulphate is precipitated, and there is a loss of hardness.

Organic Matter.—Rapid decoloration of a potassium permanganate solution indicates, as a rule, the presence of recent animal contamination. It must be remembered that iron salts, nitrites, and hydrogen sulphide will reduce

permanganate of potassium, and these, if present, must be allowed for. Or, the water, slightly acidulated, may be boiled for twenty minutes with a few drops of solution of chloride of gold. According to the amount of organic matter present, a rose, violet, or olive colour, or a violet or black precipitate, will be given (Whitelegge).

Vegetable matter alone may be comparatively harmless, even if present in large amounts. Large quantities of chlorine and ammonia and a high proportion of total solids are suggestive of sewage contamination. Microscopical and physical examination will throw light on the origin of organic matters.

Under the term 'organic matters' are included: (1) *Nitrogenous organic matters*, *ammonia*, *nitrates*, *and nitrites*, and (2) *oxidizable organic matters*, chiefly nitrogenous.

There are two methods in use to determine the nitrogenous organic matters; these are the *albuminoid ammonia process* of Wanklyn, and the *organic carbon and organic nitrogen process* of Frankland.

The Albuminoid Ammonia Process.—The following are the reagents required :

Nessler's Solution.—Thirty-five grammes of potassium iodide and 13 of corrosive sublimate are added to 800 c.c. of distilled water, which is heated to boiling until the salts dissolve ; then add a cold saturated solution of corrosive sublimate until the red periodide of mercury just begins to be permanent. To render it sensitive add 160 grammes of caustic potash, or 120 of caustic soda, and make up with distilled water to 1 litre.

Dilute standard solution of ammonia, of which 1 c.c. = 0·01 milligramme of ammonia, or 0·0082 milligramme of nitrogen.

Alkaline Potassium Solution.—Two hundred grammes of solid caustic potash and 8 grammes of pure potasssium permanganate are boiled in 1,100 c.c. of distilled water till concentrated to 1 litre.

Each analysis requires 50 c.c. of this solution—that is, 10 grammes of potash and 0·4 of permanganate.

Distilled water should be used for making up standards of ammonia. It must be very pure, and should be distilled with a little phosphoric acid to fix the ammonia (Notter).

The Process—(*a*) *Free Ammonia.*—Two hundred and fifty c.c. of the water to be examined is placed in a retort attached to a Liebig's condenser (the apparatus being scrupulously clean), and 50 c.c. are distilled over and collected in a cylinder.

Experience shows that two-thirds of the whole 'free ammonia' is contained in the first 50 c.c.; therefore, if time be an object, an approximate result can be obtained by 'Nesslerizing' the first 50 c.c., and adding one-third to the result. To obtain an accurate result, distillation must be continued till all the free ammonia has come over. The total free ammonia comes over, as a rule, in the distillation of the first 130 c.c.

The 'free ammonia' is that which is combined with carbonic, nitric, or other acids, or other easily decomposable substances.

(*b*) *Albuminoid Ammonia.*—If only 50 c.c. are used to determine the free ammonia, 100 c.c. more are distilled over and thrown away; 50 c.c. of the alkaline permanganate solution is then added, and distillation is allowed to proceed slowly, the distillate being collected in successive quantities of 50 c.c. until no more ammonia comes over.

Potassium permanganate, in the presence of an alkali, by oxidation breaks up the bulk of the nitrogenous organic matter in water, converting the nitrogen into ammonia.

Nesslerizing is the operation of finding the strength of dilute solutions of ammonia by means of the Nessler test. To 50 c.c. of distillate add 2 c.c. of the Nessler reagent. If ammonia be present in quantity, the distillate will assume a rich brown colour. The more the ammonia, the deeper the colour. In very dilute solutions a yellow tint only will be produced. Solutions containing enough ammonia to give a precipitate cannot be accurately 'Nesslerized,' as this process depends on a comparison of colours. Such solution should therefore be diluted with known quantities of ammonia-free water.

To measure the amount of ammonia a clean cylinder is taken, and into it is dropped a certain measured volume of the dilute standard solution of ammonia, and filled up with distilled water to 50 c.c. To this 2 c.c. of Nessler

reagent is now added. If the colour produced is the same as that of the tested distillate, then the test is completed. The number of c.c. of ammonia solution represents the ammonia or nitrogen in the distillate. If the two solutions are not of equal depth of colour, another standard one must be made up, and another comparison made until the colours are of the same depth.

To facilitate comparison, the Nessler glasses should be placed on a white surface. About five minutes are required to develop the full tint.

Each 50 c.c. of distillate, after the addition of the permanganate, must be tested until no colour is produced, and the amounts must be added together. The total represents the 'albuminoid ammonia.'

'In drinking-waters of good quality the albuminoid ammonia should not exceed 0·01 per 100,000. Much albuminoid ammonia, with a small amount of free ammonia, indicates usually vegetable contamination, particularly so if the chlorides, nitrates, and nitrites are low. Peaty waters commonly yield large quantities of albuminoid ammonia, which is evolved slowly and somewhat persistently. Badly polluted waters, on the other hand, generally yield their high proportion of albuminoid ammonia promptly and sharply' (Notter and Firth).

Wanklyn's albuminoid ammonia process is the method most generally used in practical work, and candidates for the Diploma of Public Health must be prepared to carry it out. Combustion processes, as Frankland's and Kjeldahl's, are preferred by many analysts, but require costly apparatus, much time, and a high degree of skill.

Frankland's Process.—The following outline of this process is extracted from Whitelegge's 'Hygiene':

'To a litre of the water are added 20 c.c. of saturated solution of sulphurous acid, to reduce the oxidized nitrogen and liberate all carbonic acid. The water is evaporated to dryness. The dry residue is mixed with oxide of copper, and heated *in vacuo* in a combustion-tube for about an hour. The gases evolved are collected over a mercurial trough. They contain all the organic carbon as carbonic acid, and the nitrogen as such. They are measured volumetrically, and after the absorption of the carbonic acid by caustic potash the residue is read as

nitrogen. The nitrogen present in the water as ammonia must be separately determined, and deducted from the total.'

Other things being equal, the lower the ratio of nitrogen to carbon, and the less the amount of each, the greater is the purity of the water. A low proportion of nitrogen to carbon (1 to 8) indicates vegetable organic matter ; a high proportion, such as 1 to 3, is pretty certain proof of animal pollution. The Rivers Pollution Commission held that 'a good drinking-water should not yield more than 0·2 parts of organic carbon or 0·02 of organic nitrogen in 100,000 parts.' The relation of carbon to nitrogen should not be less than 7 to 1.

The term 'total combined nitrogen' includes organic nitrogen and nitrogen as nitrates, nitrites, and ammonia. This is recorded by Frankland as '*previous sewage contamination*.'

Comparison of the two methods: Frankland's is a much more tedious and difficult process than Wanklyn's, hence more liable to error.

In the Frankland process there is a risk that the organic matter may be destroyed during the evaporation to dryness, or by the preliminary destruction of the nitric acid. The small quantity of organic matter existing in water is insufficient to admit of a correct organic analysis.

To Wanklyn's process the objection is taken that the proportion of ammonia evolved varies widely with the different kinds of organic matter submitted to the reaction, but it is claimed that the 'albuminoid ammonia' can be looked upon as an index to the nitrogenous organic matter, as valuable in itself as a determination of the total nitrogen would be, and more valuable in the certainty with which the results can be obtained. The 'albuminoid ammonia' is not the total amount of ammonia which the albumin is capable of giving, but is about two-thirds of the total quantity—this is, however, a fairly constant fraction.

Kjeldahl's Process is based upon the conversion of the nitrogen of organic substances into sulphate of ammonia if charred by heating with strong sulphuric acid. The water is concentrated by distillation, and

charred by strong sulphuric acid. The organic residue is then broken up with permanganate of potash in the presence of a caustic alkali. On further distillation the organic nitrogen is determined from the resulting ammonia by Nesslerizing. The organic nitrogen by Kjeldahl's process is about twice the nitrogen of the albuminoid ammonia, and in usable drinking-water does not usually exceed 0·016 parts per 100,000. Any water, unless peaty, containing more than this may be regarded with suspicion (Notter and Firth).

Nitrates and Nitrites are produced by the passage of sewage through earth, ammonia being changed first to nitrites and then to nitrates by the action of certain micro-organisms; but the presence of nitrates cannot be taken as necessarily pointing to sewage contamination, as many pure waters are often highly charged with nitrates from the passage of the water through geological strata containing nitrates. Such waters have no organic impurity. Nitrates are removed by the processes of vegetation. Nitrites also may be present from other sources than sewage, as through the reduction of nitrates by metals, cement, new brick-work, etc.

Nitrates* may be estimated quantitatively by the following methods:

1. *Aluminium Process.*—The oxidized nitrogen is converted into ammonia by means of metallic aluminium acting in a pure solution of caustic soda, free from nitrates, and generating nascent hydrogen. The liquid is then distilled and Nesslerized. The ammonia found after deducting the free ammonia originally present in the sample will correspond to oxidized nitrogen, each milligramme representing 0·82 of oxidized nitrogen per 100 c.c. of sample, or parts per 100,000.

2. Or by the *Copper-zinc Process.*—Zinc foil is immersed in a solution of copper sulphate until the zinc is covered with a deposit of copper. It is known as a 'wet copper couple.' A piece of this is put with the water to be examined, and after ten or twelve hours, when all the nitrous acid has been converted, the liquid is distilled and Nesslerized, and the amount of nitric acid calculated

* Strictly speaking, the following tests apply to oxidized nitrogen—that is, nitrates and nitrites indifferently.

from the ammonia, any ammonia already determined being deducted first.

3. Or by *Crum's Method.* — A nitrate shaken with strong H_2SO_4 and an excess of mercury is decomposed, NO being liberated as a gas and measured.

4. Or by the *Phenol-sulphuric Acid Method.*—A small amount of water is evaporated to dryness, phenol-sulphuric acid is added, and thoroughly mixed by means of a glass rod. If nitrates are present the liquid will turn red quickly or slowly, according to the amount. Pure water is now added, and the colour of the solution compared with that of a standard solution.

The above tests apply to nitrates and nitrites indifferently.

Nitrites may be estimated quantitatively by means of solutions of metaphenylene diamine and sulphuric acid, producing a red colour, which is to be compared with a standard, as in the Nessler process (Griess), or by means of Ilosvay's solution (sulphanilic acid and naphthylamine), or they may be determined by the permanganate process (see below).

In stating the results obtained, various methods are followed, some chemists giving them as free and albuminoid ammonia, nitrates and nitrites; others resolving the last two into nitric and nitrous acids; while others, again, reduce all to *nitrogen.*

De Chaumont gives the following co-efficients:

1 part of $NH_3 = 3{\cdot}706$ nitric acid, $HNO_3 = 3{\cdot}647$, $NO_3 = 0{\cdot}8235$ nitrogen N.

1 part of $NH_3 = 2{\cdot}765$ nitrous acid, $HNO_2 = 2{\cdot}706$ NO_2.

Oxidizable matter may comprise ferrous salts, hydrogen sulphide, nitrites, or organic matter. The two former can easily be detected; the two latter are the more important, and may be estimated by the use of standard solutions of permanganate of potassium and sulphuric acid.

To determine the amount of oxidizable organic matter present, *Tidy's method* is usually employed. The water to be tested is acidulated and heated in a water bath, and standard permanganate solution added until a permanent

pink colour is established. The amount of permanganate necessary to effect this will be the measure of the amount of oxygen absorbed.

The amount of permanganate remaining unreduced is measured by adding solution of potassium iodide. The oxygen left available will immediately act upon it, setting free a proportionate amount of iodine, and turning the solution yellow. The free iodine is absorbed by adding standard hyposulphite of soda solution from a burette till no more remains. The exact moment when all the free iodine has been removed is ascertained by means of an indicator of starch solution, which will give a blue tint so long as any free iodine is present. The moment the blue colour has disappeared, the amount of hyposulphite solution used is read off.

As the hyposulphite solution is very unstable, a blank test with distilled water is performed in every experiment as a control.

It is usual to estimate separately the oxygen consumed in fifteen minutes and three hours respectively. The latter represents the total amount of oxidizable matter present, while the fifteen minutes reaction indicates the amount of readily oxidizable, putrescent, and presumably dangerous matter.

Every c.c. of permanganate solution used corresponds to a definite amount of oxygen absorbed, deduction being made for the hyposulphite expended. The remainder of the oxygen is attributed to the sample water. If nitrites or hydrogen sulphide are present in the sample they must be separately allowed for.

Blair's Oxygen Process is similar to Tidy's, the same reagents being used, but of different strength.

It is useful, in deciding between ammoniacal deep-spring and sewage-polluted waters, to know the oxygen required.

Chloride of gold may be used to detect the presence of oxidizable matters. The water should be neutral or feebly acid, and must be boiled for twenty minutes with the reagent. The colour changes from rose-pink to violet, then to olive, and there may be a black precipitate. If no nitrous acid be present, the reaction may generally be considered due to organic matter.

Phosphates are seldom present in water except in the smallest traces, as phosphates, being acid salts, are incompatible with calcium carbonate. They generally indicate remote sewage pollution, but need not condemn a water if other indications are satisfactory.

The water is concentrated to one-fiftieth, nitric acid is added, and then a solution of ammonium molybdate. If phosphates are present a yellow precipitate will occur on standing, which can be collected on a filter, dried, and weighed. The quantity, if too small to weigh, may be recorded as 'traces,' 'heavy traces,' or 'very heavy traces.'

Sulphides may be due to the reduction of sulphates by *Beggiatoa alba*, or from contact with iron pyrites. Carbonic acid liberates H_2S from sulphides. Medicinal sulphuretted waters are well known to have a purgative action. They may, if necessary, be measured by the nitroprusside of sodium test after fixing with a caustic alkali.

Poisonous Metals.—Lead, iron, and copper are the poisonous metals more usually met with in drinking-water; less than one-tenth grain of lead or copper, and not more than two-tenths grain of iron, per gallon may be permitted.

Lead is estimated by a colorimetric test by adding ammonium sulphide, and comparing the colour with that of a standard solution.

Iron is measured by fixing with potassium permanganate, to convert any iron present to the ferric state, acidulating with nitric acid, concentrating, and adding potassium sulphocyanate solution. The blood-red colour produced is compared with that of a standard solution of ferric sulphate. In practice a glass rod moistened with ammonium sulphide is dipped into some water in a porcelain dish. If there be any coloration, it should just be visible, and should disappear on the addition of 2 or 3 drops of hydrochloric acid if it be due to iron; if it remains, it is due to copper or lead, and the water should be condemned. Arsenic, barium, zinc, manganese, and chromium sometimes find their way into drinking-water from chemical and other works. The least trace of these latter metals or of copper should condemn any water.

Dissolved oxygen may be estimated by *Thresh's method.* Measured quantities of sulphuric acid, sodic nitrite, and potassic iodide are added to the sample. The nitrous acid acts as a carrier until all the dissolved oxygen is exhausted, liberating a proportionate amount of iodine. This is measured by a standard solution of hyposulphite of soda, with solution of starch as an indicator, as in Tidy's method (*vide supra*).

Interpretation of Results.—In judging samples of water no safe conclusion can be drawn merely from the results of chemical or bacteriological examination considered without reference to the source of supply. Of course, any positive indications of sewage contamination or specific infection should condemn a sample ; but, apart from such evidence, full knowledge of the source of supply is essential to the formation of a sound judgment. Thus we require to know the nature of the source, as deep or shallow well, etc. ; its site, and whether there is any possibility of contamination locally by soakage or otherwise ; the geological conformation of the district and the strata through which the water has passed ; and the average character of the waters in the district.

Thus *chlorides* are found in large quantities in organically pure brackish water and in certain salt-bearing strata, as the new red sandstone, green sand, etc., and under these circumstances need not of themselves excite suspicion ; but when they are found in a sample in excess of the amount occurring in the average water of the district they should excite strong suspicion of sewage contamination, especially if there is also excess of organic matter or oxidized nitrogen. Similarly, the presence of oxidized nitrogen may be held generally to be evidence of sewage contamination recent or remote, though nitrates may be derived from certain strata, as from the chalk. Generally speaking, nitrites may be held to indicate recent and dangerous sewage pollution.

Rain-water often contains a large amount of free ammonia, probably derived from soot, and harmless. Albuminoid ammonia may be found in comparatively large amounts in peaty waters, in which case it will probably distil over slowly. If distilling over-rapidly, and especially if combined with a high proportion of chlorides

and oxidized nitrogen, it points to sewage contamination. Peaty waters will also yield a high proportion of oxygen absorbed, which is disengaged slowly. If the oxygen is rapidly disengaged, and the fifteen minutes reaction shows a high return, it is probably due to putrescible matter. Here, again, the amount of chlorides and oxidized nitrogen must be taken into consideration.

In Frankland's combustion process not only the amounts of C and N, but the ratio of N to C must be taken into account. A high ratio of N to C points to sewage contamination. Peaty waters may yield a large amount of C, but the N should be in a low ratio to it, not exceeding 1 N to 8 C. A ratio of 1 N to 3 C is pretty certain proof of animal pollution.

Bacteriological Examination. — Micro-organisms multiply so rapidly in water that little or no importance can be attached to the mere number of colonies found, unless the sample is examined immediately after collection, or the sample carefully kept in ice. Positive evidence of specific infection is, of course, of crucial value, but mere negative evidence can never be regarded as final. Chemical analysis has pronounced water to be good when it was known to contain cholera excreta in the proportion of 1 part per 1,000; on the other hand, neither the cholera bacillus could be found in the water used at Hamburg nor the *Bacillus typhosus* in the water which produced the epidemic at Worthing in 1893. Analysis can indicate degrees of impurity and danger, not standards of purity and safety (Wilson).

The possibility of occasional pollution is a point too often overlooked, yet it is to such accidental pollution that outbreaks of disease are most frequently attributed; and of the liability to this the examination of samples of water prior to the occurrence of the contamination may tell us little or nothing.

CHAPTER III.

REMOVAL AND DISPOSAL OF EXCRETA AND REFUSE, ETC., AND CLEANSING OF TOWNS.

It is essential that all refuse should be removed as speedily as possible from the vicinity of dwellings. These refuse matters consist of fæces, urine, waste-water from houses and factories, washings from roadways, stables, etc., and of ashes, dust, road-sweepings, etc.

Excreta (Human).

Daily amount of solid excreta per head averages	$2\frac{1}{2}$ ounces.
Daily amount of solid excreta per male adult averages...	4 ,,
Daily amount of fluid excreta per head averages	40 ,,
Daily amount of nitrogen per head averages	150 grains.
Daily amount of urea (CH_4N_2O) per head averages...	500 ,,
Daily amount of uric acid ($C_5H_4N_4O_3$) per head averages	$8\frac{1}{2}$,,

Fæcal matters and urine are acid at first, and will remain so without decomposition for some considerable time if they are kept separate; but if fæces and urine are mixed, decomposition, with the formation of ammonium carbonate, takes place within twenty-four hours.

Decomposition of fæces free from urine yields organic fœtid substances, but sulphuretted hydrogen is seldom present. When heated, carburetted hydrogen is given off largely. When urine or water is present, ammonia, light carburetted hydrogen, nitrogen, and carbon dioxide are evolved; the liquid generally contains ammonia and sulphuretted hydrogen. Urea is the chief nitrogenous body present, but it is soon transformed into carbon dioxide and ammonia.

The waste-waters from the various sources stated above are often as foul as ordinary sewage.

The various plans for the removal of excreta may be primarily divided into two classes:

1. The water method.
2. The dry methods.

1. The Water Method.

Necessary conditions are a good supply of water, good sewers, ventilation, a proper outfall, and means of disposal of the sewer water.

Water.—Twenty-five gallons per head per diem are required to keep ordinary well-laid sewers clean, but extra water has to be used from time to time for flushing purposes.

House Drainage.—Water-closets should, if possible, be placed in an outbuilding or projection from the house, with through ventilation between it and the house. The windows, which should be not less than 2 square feet in area, ought to open to the ceiling, or the closet must be ventilated through the roof by a tube, or through an external wall by means of air-bricks. It is better to have a water-closet near the roof than in the basement. The best model for hospitals or large buildings is a turret separated from the main building by a passage having windows to admit of cross ventilation. In ordinary houses one at least of the sides of a water-closet must be in an external wall, which should abut immediately upon an open space. According to the London Model By-laws, the space should be not less than 100 square feet of superficial area measured horizontally at a point below the level of the floor of such closet, except in the case of any water-closet constructed below the surface of the ground, and approached directly from an area or other open space available for purposes of ventilation, measuring at least 40 superficial feet in extent, and having a distance across of not less than 5 feet, and not covered in otherwise than by a grating or railing. A water-closet that is approached from the external air must have a floor of hard, smooth, impervious material, having a fall to the door of ½ inch

to the foot, and should be provided with proper doors and fastenings. A water-closet which abuts on any side on a room intended for human habitation, or used for the manufacture, preparation, or storage of food for man, or used as a factory, workshop, or workplace, shall be enclosed by a solid wall or partition of brick or other materials, extending the entire height from the floor to the ceiling.

Closet-pans are of various kinds, but in all of them the essential thing is that they should be *self-cleansing*. The old *pan-closet*, with a filthy container beneath, and an equally objectionable D-trap between it and the drain (forbidden under the Model By-laws), and the *long-hopper* closet, are still to be met with. Neither form is self-cleansing.

Better forms are the short-hopper, the wash-out, the valve, the plug, and the trough. There are also various modifications, as the slop-water closet, the syphonic, etc.

The pan, basin, or other receptacle should be of non-absorbent material, and of such shape, of such capacity, and of such mode of construction as to receive and contain a sufficient quantity of water, and to allow all filth which may from time to time be deposited in it to fall free of the sides thereof, and directly into the water.

A *short-hopper* closet should be a cone with a straight back, a circular flushing-rim, and fixed over an S-trap 4 inches in diameter, with a water-seal of not less than 2½ inches, and an easy curve. The seat is often made hinged, so that the closet may be used as a urinal or slop-sink, and the basin made in pedestal form unenclosed by woodwork. When not in pedestal form the pan and trap may be protected by being enclosed in a block of concrete.

In many forms of long or short hopper closets the area of water exposed is too small, or does not rise high enough in the basin. A good type steering clear of this fault is the syphonic, the surface of water in the basin of which is 12 by 10 inches, 6 inches deep, with 3 inches of water-seal.

The water-supply should not be less than 2 gallons for each time of use. Many medical officers contend that

3 gallons should be allowed. The amount and force should be sufficient to wash everything through the syphon-trap beneath. Water-waste-preventing cisterns only should be connected directly with the supply of water-closets. The best are those that work by syphon action, one pull of the wire being sufficient to set it going. The cistern should be at least 4 feet above the pan, and should be connected by a pipe and union of not less than $1\frac{1}{2}$ inches internal diameter.

The *wash-out* closet has a receptacle containing a little water to receive the excreta. The rush of water clears the contents of the basin over the edge into a short, straight pipe leading to a syphon trap. They are not easily kept perfectly clean, even with more than 2 gallons of water at each flush, as the edge of the basin breaks the force of the water. In order that some water may remain in the receptacle, these closets are fitted with a small chamber which discharges some water into the basin when the main body of water has rushed away. This is called 'an after-flush.'

Valve-closets should have an overflow pipe which should be covered by the valve when open to prevent unsealing, or the overflow pipe should be led to the open air, so that water flowing from it would act as a warning. Waste-water-preventing cisterns cannot be used with valve-closets, as they require from 6 to 8 gallons to properly cleanse them. There must also be an 'after-flush' produced as above, or by the use of a 'bellows regulator' working with the handle. A syphon or an anti-D-trap should be attached to these closets. The 'safe-tray' beneath the basin should have the waste-pipe carried out to the open air.

The *plug-closet* consists of two communicating basins — one is the receptacle for fæces, the other is in connection with the drain, from which it is cut off by a plug attached to a handle. Both chambers contain water, which is released by pulling up the plug. A syphon-trap should be used to prevent passage of foul air when the plug is up. Like the valve, the plug is apt to become leaky, or to be obstructed by paper, hair, etc., especially if slops be emptied down them.

Trough-closets may be used for groups of cottages,

factories, etc. Under a number of closet-seats arranged in a line a stoneware trough is placed for receiving the excreta. Usually there is a weir at one end, which keeps a few inches of water throughout the length of the trough, which is flushed by the use of a Field's automatic flush-tank, regulated to act as often as the necessity of the case requires. Plenty of water and frequent flushing are necessary. A syphon-trap covered with a grid to intercept brushes, cloths, etc., which may be thrown into the trough should be placed between the trough and the drain.

Slop, or Waste-water Closets.—Where a sewer is available, but where there is no regular supply, or only a small supply of water laid on, or where the apparatus is liable to rough usage, or where the water-service to a closet is liable to injury from frost, a closet may be constructed to utilize the waste-water from sinks, baths, yards, etc. The water is caught in a tipper or metal vessel balanced on pivots, so that, when full (3 or more gallons), it tips up and discharges the water.

Traps are only auxiliaries to a good drainage system (Eassie); reliance should not be placed in them solely. They are open to the following drawbacks: The amount of water contained in them may not always resist the pressure of sewer air; the water may dry up from disuse, or may be sucked out by syphon action set up by passage of water past the outlet (this can be obviated by an antisyphonage pipe). If the contents of the trap are not frequently changed, gas may be absorbed from the drain or evolved from the trap, and given off on the surface.

Essentials of a good trap:

It must be *self-cleansing*.

It must be properly laid; the outlet must be lower than the inlet.

Water must pass along frequently.

The water-seal should be at least $1\frac{1}{2}$ inches in depth.

It must be in proper proportion to the size of pipe. A too large trap will lead to deposit forming; too small a pipe running full will produce unsyphoning. A 4-inch trap is large enough for a 6-inch pipe.

It must not be liable to be forced by the pressure of sewer gas.

Proper ventilation of the drain must therefore be provided. All traps are liable to stoppage, and should therefore be readily accessible.

Varieties of traps, though numerous, may be classified under four groups :

(*a*) The syphon is a deeply-curved pipe like the figure S, in which the whole of the curve is always full of water. It is a good form of trap. Two syphons must not succeed each other in the same pipe, or one will suck the other empty. At the crown of the trap there should be an air-vent, carried to the outer air, and if from a trap below a water-closet to a point as high as the top of the soil-pipe. Should there be several traps on different floors one above the other, the action of the higher ones will unsyphon the lower unless antisyphonage is provided for as follows: Two-inch branch-pipes taken from a point not less than 3 and not more than 12 inches from the highest part of each trap, and on that side of the water-seal which is nearest to the soil-pipe, are connected with one 3-inch main air-pipe, which is connected at its top to the soil-pipe above the highest water-closet, the soil-pipe being carried full size up to the roof.

The 'anti-D' trap is a lead syphon-trap in which the calibre is diminished in the bent portion, and the end of the pipe beyond the curve is square instead of circular. The constriction increases the force of the water as it passes through, and thereby cleanses the whole trap ; the square section of the outlet causes some obstruction to the water, and thus assists in the prevention of syphonage.

(*b*) The midfeather includes such objectionable traps as the dip, D, Bell, Antill, Liverpool, etc. They are not self-cleansing, and if not used regularly become dry and worse than useless.

(*c*) The flap-trap used to be put between the drain and the sewer, in the hope that it might prevent reflux of sewer air. A brass flap may be put over the mouth of pipes opening over gratings to prevent cold air passing into the house, and to keep birds out.

(*d*) The ball-trap is one in which a ball covers an orifice, which it ought perfectly to block up ; but, as

with the flap-trap, paper, etc., will easily prevent proper action.

Grease-traps are used in connection with kitchen sinks, but are apt to be a source of nuisance if the decomposing fat be not frequently cleared out. For this purpose a syphon-trap answers well. If placed immediately below a sink, it should be provided with a screw-cap at the base of the curve, by which it may be cleansed. If placed in a yard or area, a small, automatic flush-tank should be connected with it to insure its thorough cleansing at regular intervals.

For stables and yards a trap or gully should be used, which will catch and deposit straw, etc. Dean's is a useful form, being provided with a movable bucket.

The *soil-pipe* passes from the water-closet to the main drain of the house, and should be placed outside the wall. It should be also continued upwards, to act as a ventilator, in undiminished bore and without avoidable bends, to such a height and in such a position as to afford by means of the open end a safe outlet for foul air, and so that such open end shall in all cases be above the highest part of the roof of the building to which the soil-pipe is attached, and where practicable be not less than 3 feet above any window within 20 feet measured in a straight line from the open end of such soil-pipe (Model By-laws). It should be 6 feet distant from any chimney. The open end should be furnished with a wire-guard covering, the openings in the meshes of which shall be equal to not less than the area of the open end of the soil-pipe.

No rain-water pipe must be used either as a soil-pipe or as a ventilating shaft. Soil-pipes are made of drawn lead or of iron, coated in and out with Angus Smith's composition. All junctions of closet and soil-pipe and of the various lengths of soil and ventilating pipe must be securely made.

A soil-pipe is generally required to be of 3½ or 4 inches internal diameter. Its weight in proportion to its length and internal diameter should be follows:

Diameter.	Lead. Weight per 10 feet length; not less than—	Iron. Weight per 6 feet length; not less than—
$3\frac{1}{2}$ inches	65 lb.	48 lb.
4 "	74 "	54 "
5 "	92 "	69 "
6 "	110 "	84 "

Junctions in lead pipes should be made by 'wiped joints'; in iron pipes with molten lead, properly caulked. On joining lead with iron or earthenware and iron with stoneware, a brass socket or thimble is inserted between the two dissimilar materials, being fixed to lead by a wiped or overcast lead-joint, to iron by a molten lead-joint, and to earthenware by a joint made with Portland cement.

Doulton's 'metallo-keramic' joint, being glazed on to the earthenware, permits lead to be soldered on direct without the necessity for a brass thimble.

The water-service pipe to the closet basin may be joined by means of putty and red lead or of a rubber socket.

Overflow and waste-pipes from cisterns, tanks, urinals, lavatories, baths, safes of water-closets, sinks, etc., and all rain-water pipes, must not be connected directly with a drain, but must be taken through an external wall and empty in the open air over a grating covering a water-trap or immediately under it; but nothing must interfere with the passage of air through the grating to the openings of the pipes, and the grating must be so constructed that the aggregate extent of the apertures in it shall not be less than the sectional area of the pipes or drains to which it is fitted. All sink or waste or overflow pipes should be trapped.

Automatic flushing-cisterns are of two kinds: (1) The 'tipper,' similar to that used in waste-water closets; (2) a tank or cistern, in which, when the water reaches a cer-

tain height, syphonage is started, which rapidly empties the cistern. The cistern is filled by means of a tap or ball-valve with reverse action. In flushing drains facility must be given for the escape of air displaced.

The *house-drain* is the continuation of the soil-pipe, the junction being made by a curved pipe. No junction should be rectangular. It is advisable that it do not run beneath the house, but if it must do so, it should be completely embedded in and covered with concrete at least 6 inches thick all round. If not under the house, the drain should be laid on a concrete bed not less than 6 inches in depth, and extending at least 4 inches on both sides of the pipes. The remainder of the trench should be filled in with good, dry, sound earth, ballast, or rubbish, carefully rammed to a level with the surrounding ground.

Drains should be laid in straight lines where practicable, with an even and regular inclination from the lowest level upwards. Any departure from a straight line should be made with a suitable curved pipe, and if possible an inspection chamber or 'eye.' Diminution is made in the size of a drain by the introduction of a proper reducing pipe—say, in enlarging a drain from 4 to 6 inches, a reducing pipe is used 4 inches in diameter at one end and 6 inches at the other; thus the bore of the drain is kept level.

Drains may be constructed of stoneware or iron (coated with Angus Smith's anticorrosive composition inside and out).

The pipes are usually 4 or 9 inches in diameter, the smaller size being suitable for small houses or branch drains, the larger for large main drains. Stoneware pipes should be jointed with cement, unless Sykes' patent joints are used. Iron pipes are jointed with molten lead and properly caulked. Care must be taken in laying drains that the alignment of the invert is secured free from obstructive ledges at the joints, and the interior of pipes must be cleared of any cement which may project from the joints.

All junctions of one line of drain-pipes with another should be made at the sides of the pipes, and preferably in an inspection chamber, so that the drains may run in

straight lines from one point of access to another. No pipe must join another at a right angle, either vertically or laterally ; curved or oblique junctions are necessary.

Four-inch pipes require a fall of				1 in 40.
Six-inch	„	„	„	1 in 60.
Nine-inch	„	„	„	1 in 90.

A usual minimum gradient to require in house-drains is 1 in 48, equal to ½-inch in each 2-feet pipe length.

Should the fall not be sufficient, it is necessary to provide a flush-tank. All drains and pipes should be washed out at least once a month.

The house-pipe must not enter the sewer directly, but must have a good air and water-trap intervening. It is most important that a good supply of fresh air enter the drain, so as to thoroughly ventilate it. This is attained by placing an intercepter syphon-trap as near as possible to the sewer and beyond all branch connections with the inlet and raking or cleansing arm in an inspection chamber, the walls of which are built in white glazed brick. The drains within the chamber are formed of half-pipes set in cement, the space between the pipes being sloped and rendered smooth. The chamber should be provided with a fresh-air inlet not less than 3 inches in diameter, the pipe from which is carried up to the outer air and fitted with a mica valve to prevent back draught, or else carried above the roof-level. The chamber is fitted with a movable air-tight iron cover.

Inspection and Testing of Drains.—No drain should be passed as satisfactory without being inspected in its whole length before it is covered up, and without being tested, no matter how good the supervision of the workmen may have been.

Tests for Drains.—For pipes that are exposed smoke or volatile chemicals are used ; for those below ground the water or air-test is required.

Smoke Test.—Smoke is pumped into the drainage system for a longer or shorter period from a smoke-generating apparatus, all openings such as ventilating-pipes being plugged. When the inspector is satisfied that smoke is circulating throughout the drain, a thorough inspection of the house and its surroundings should be

made to discover any trace of smoke that may be issuing from the drain or sanitary fittings. For short sections a smoke-rocket may be used.

Olfactory Test.—Crude oil of peppermint, about ½ ounce, may be introduced into the highest closet, sink, or soil-pipe, and washed through the trap with a bucket of very hot water, the doors and windows being closed, and several persons stationed about the house to observe, and if possible locate, the smell of the oil. The oil is sometimes poured down the ventilating-pipe, which is then plugged, or it may be introduced into a closet-pipe in a glass capsule, and liberated on the further side of the trap by means of a drain grenade or 'ferret,' in which the pulling of a string acts on a spring which breaks the capsule. Grenades containing pungent volatile chemicals readily detected may also be used.

Hydraulic Test.—The lower end of the pipe is closed by screwing in an expanding drain-stopper, or inserting and inflating an indiarubber bag. The pipe is then filled with water. If it be sound, the level of the water will remain constant; if not, it will sink, and an approximate estimate of the extent of the breakage can be made from the rate of subsidence.

The drain-stopper consists of two iron plates, between which a rubber ring is fixed. On screwing the plates together the rubber is forced outwards, and so plugs the pipe. There should be a centre outlet to permit the water to run off slowly.

An 'indicator' or other gauge may be connected with the outlet of the plug, by means of which the rate of subsidence can be accurately measured.

A drain may prove leaky by the water-test which was not so previously, as the pressure of the water may cause any weak parts of the jointing to give way. The water-test should be used periodically, as it is possible that in course of time a slight settlement might take place in the pipes, with disturbance of the junctions.

By means of an expanding bag the drain may be tested in short lengths, and the situation of the leakage precisely located. The hydraulic test should invariably be applied to all new drains, and no drain can be considered satisfactory that is not capable of withstanding this test.

The *Pneumatic Test* is a very difficult one to perform, as leakage is apt to occur. The pipe must be plugged. Air is pumped in, and the pipe connected with a pressure-gauge, by which any escape can be detected.

The *Mirror Test* is very useful for discovering sagged joints, etc., and localizing them. A lighted candle is placed at one end of the drain in the inspection chamber, and the mirror is placed at an angle at the other. By standing over the mirror the interior of the pipe is viewed, and any defect may be noted. The number of the defective joint from either end should be recorded (Fletcher).

When water is run down any house-pipe, even the soil-pipe, there should be no smell if the pipe is well ventilated and the traps are acting properly. It should be noticed whether the water runs away at once, or if there is any check, and a light held over the entrance to the pipe or trap will show if there is any reflux of air with or without water being poured down.

If the drain can be seen into, some lime mixed with water may be poured down the house-pipe, and its condition as to colour, flow, etc., noted at the opening.

If gas bubbles up on stirring the water in any trap it shows great foulness, or else the trap is seldom used.

Main Sewers.—Sewers are constructed according to the purposes they are to serve. They may carry off house and trade water, or solid excreta in addition, or one or both, with the rainfall. Sewers are made either circular or egg-shaped, of glazed earthenware, or of impervious brick moulded in proper shape and set in Portland cement. They are laid on a sound foundation, and arrangements are made to carry off subsoil water under the drain.

All should be accessible by manholes, and be laid in straight lines from hole to hole. Junctions of sewers and curves should be made at a manhole by means of open half-pipes. The radius of any curve should not be less than ten times the cross sectional diameter of the sewer.

Drains entering a sewer should do so in the upper segment and in the direction of flow. Circular pipes are used for smaller sewers up to 18 inches. Above this

diameter egg-shaped or oval sewers are used, especially when there is a varying flow. They are laid with the invert or small end down, because there is a greater depth of fluid with a smaller exposed surface. A maximum scouring effect is produced with a small quantity of water.

Velocity of flow in sewers should never be less than 2 feet per second, nor more than 4 feet per second. If less than the former deposits occur, and if more than the latter the invert becomes quickly worn out. All the sewers in a system should have the same velocity—about 3 feet per second—throughout the whole course, and the fall requires to be equable and arranged according to the size of the pipe. Thus the fall varies from 1 in 244 in a 15-inch sewer to 1 in 784 in a 48-inch sewer.

In some districts it is impossible, from the uniform flatness of the ground, to get proper gradients, in which case special arrangements must be made. Either locks or gates are provided to various sections of pipe, so that the contents may be retained for a time, and suddenly set free, thereby flushing the next section. Or automatic flush-tanks or tippers can be used, or Shone's pneumatic ejector. In this contrivance sewage flows into a chamber by gravitation, and is then forced by means of compressed air out through a discharge-pipe at a higher level. The ejector is also useful for discharging sewage into the sea against the rising tide, thus preventing the sewers being 'tide-locked.' The outfall sewer need not be so large as when gravitation only is depended upon.

By Adams' method sewage may be raised from a low level to a high-level sewer by utilizing a head of water or of sewage to compress the air in an iron vessel. On being liberated, the compressed air forces the sewage from the lower-level chamber up an upcast-pipe to another sewer, or to discharge into the sea or on to land. The process is automatic.

To calculate discharge from sewers the following factors must be known.

Hydraulic mean depth=one-fourth diameter in circular pipes. In pipes other than circular it equals the section area of current of fluid divided by the wetted perimeter—*i.e.*, that part of the circumference of the pipe

wetted by the fluid. Error will be avoided if the hydraulic mean depth is reduced to a fraction of a foot.

Let V = velocity in feet per minute.
D = hydraulic mean depth.
F = fall in feet per mile.
A = section area of current of fluid.
Then $V = 55 \times (\sqrt{D \times 2\ F})$.
And VA = discharge in cubic feet per minute.

There is a point of flow in all sewers when they dis charge more than when running full (Baldwin Latham). This is due to increased friction when running full, and to obstruction by air in the pipes.

Deposits in Sewers.—The changing level of the fluid in the sewers leaves a deposit on the sides, while slimy matter, swarming with bacteria and fungi, collects on the crown of the sewers. This occurs even in well-made sewers; in badly-constructed ones with improper falls, sharp curves, want of water, or from sinking of the floor or check of flow by tides, the deposits are much worse. A sewer should discharge itself in eight hours.

Ventilation of Sewers.—No sewer is absolutely air-tight, and as the water-level is always varying, there must be provision for the admission and discharge of air, to prevent pressure of air or gas being exercised upon the house-traps. It has been usual to ventilate sewers by means of surface-gratings. Some of these will be inlets, others outlets.

On main sewers there should be a grating every 50 or 100 yards, with a tray to catch dirt falling through from the roadway. In addition to these gratings, or in place of them, in narrow streets upcast shafts (one for every 20 feet of sewer) may be carried up houses or trees; the surface-gratings would then act as inlets.

In some places hollow lamp-posts with gas-jets inside have been used for the ventilation of sewers. The gas-jet creates a strong upward current, and, it is claimed, destroys all effluvia and organisms. They should be placed on the highest practicable gradients, especially at the end of cul-de-sacs, with openings at the lowest parts for the admission of fresh air. Each lamp is capable of exhausting 3,000 cubic feet of sewer air per hour. Another

plan consists in the placing of 'tumbling-bays' at intervals along a steep gradient. The air then is forced up the nearest ventilator instead of rushing up to the higher parts of the sewer.

Destructors may be of value, but the best remedy against sewer-gas is the regular flushing and cleansing of sewers, for no amount of fresh air that can be passed into filthy drains and sewers can render them innocuous and inoffensive. Precautions should be taken to prevent the blowing-off of steam, and the entrance of hot water and dangerous chemicals into sewers.

The separate system is a modification of the usual wet method of removing excreta, and is based on the principle of sending 'the rain to the river, the sewage to the soil.' It is a form of drainage recommended by Professor Corfield.

Advantages.—Smaller sewers, smaller amount of sewer water to be dealt with at the overflow, more fertilizing constituents, more regular flow, absence of débris from roads, storm-waters do not flood the houses in the lower parts of the town, and if irrigation be the method of disposal of the sewage, heavy rains will not interfere with it.

Disadvantages.—Two sets of pipes have to be provided. Rain-water carries with it much organic débris from the air, roofs, yards, and streets, and thus pollutes streams. Additional flushing may be required for the sewers.

This system is valuable when a town is low, and it is expensive to lift sewage ; when land cannot be obtained ; when the natural contour of the land is very favourable for the flow of rain in one direction and of sewage in another. In countries with long dry seasons and heavy rainfalls this system is too expensive.

The interception system is so called because the solid excreta are retained in a perforated receptacle which allows the fluid part to drain away. This collection of filth in the basements of houses is most objectionable.

Disposal of Sewer-Water.—It is very often a difficult matter to decide in which way excreta and sewer-water are ultimately to be disposed of. It is certain, however, that storage in cesspools, and discharge without purifica-

tion into running water,* are plans which must be unhesitatingly condemned, although these means of disposal are to be found in many towns. The chief aim ought to be to remove all refuse matters as quickly as possible from the neighbourhood of houses.

The methods of disposal of sewer-water are as follows:

Discharge into the Sea.—The outlet-pipe should always be under water, even at low-water. If the sewage cannot be carried out well to sea, it will be thrown up on the beach and cause a nuisance. To prevent this, great care must be exercised in the selection of the site for the outfall, and observations should be made, not only of the surface-tides and currents, but also of those at different depths; and the effect upon the sewage by its different specific gravity from that of salt-water must be allowed for, as well as the difference of level of the tides, and the configuration of the adjoining coast-line (H. P. Boulnois). In certain cases, therefore, the Local Government Board reserve the right to prohibit the passage of sewage into the sea.

Contamination by sewage-matter of the foreshores of seaside towns is the source of a large amount of enteric fever, which is conveyed both by the infection of oysters and other mollusca, especially cockles, and in other ways.

Discharge into Streams.—When sewer-water passes into a river it undergoes some amount of purification, mainly by subsidence, whereby many micro-organisms are, often very rapidly, removed. But it is now known that various pathogenic microbes may retain their vitality for long periods in water, and in the mud into which they may have subsided (P. Frankland). In times of flood these organisms may be stirred up and carried down stream; and as at these times, owing to flooding of filter-beds and increased rapidity of flow, filtration of water-supplies is often less efficiently conducted than usual, the danger is the greater.

In a lesser degree every water is also purified by plants, infusoria, fish, etc., by slow oxidation of nitrogenous

* *Vide* § 17, The Public Health Act, 1875; also The Rivers Pollution Prevention Acts, 1876 and 1893, and Public Health Amendment Act, 1890.

organic matters by aid of micro-organisms into nitrous and nitric acids and ammonia; but ova, epithelium, etc., will be unchanged for long periods; hence river purification is not to be depended on.

The finely-diffused solid particles are hurtful to fish, choking their gills, while the water is deprived of the oxygen necessary for the fish.

Under the Rivers Pollution Prevention Acts, 1876 and 1893, no sewage-matter may be lawfully passed into any stream unless it can be shown that the best practicable and available means are being taken to render the sewage harmless.

Disposal of Solids.—Numerous devices have been resorted to with a view to get rid of the more solid part of the sewage, and allow the fluid part to pass into streams or over land. These plans may be arranged under the headings of:

1. Subsidence, (*a*) with complete rest; (*b*) during slow but continuous flow.
2. Mechanical straining and filtration.
3. Chemical filtration, or percolation through materials exerting some chemical or oxidizing action on organic matters.
4. Precipitation by the addition of chemicals.
5. Electrolysis.
6. Aeration.
7. Sterilization by the addition of chemicals.
8. Nitrification by the action of microbes.
9. Irrigation, or the utilization of organic matter as food for growing crops.

Two or more of these processes being often employed in combination.

It is now fully recognised that the destruction and decomposition of organic matter in Nature is due mainly to bacterial action, and on this principle is founded the biological treatment of sewage which forms the basis of most modern systems of sewage disposal, wet or dry. Systems which aim at oxidation and destruction of organic matter by chemicals, or at sterilization and disinfection by the destruction of micro-organisms, and consequent arrest of putrefaction, are opposed to Nature's processes, and in practice have not proved successful.

The principal methods in use for the purification of water-carried sewage falls under one of the two following heads:

1. The *Septic Tank* system, by which it is claimed that crude sewage can be purified without the production of any appreciable quantity of sludge by exposure in closed tanks to the action of anaërobic bacteria, which disintegrate most of the suspended, and a considerable portion of the dissolved, matter.

2. *Bacterial Contact Beds.*—In these the sewage is exposed to oxidation and nitrification by the action of aërobic nitrifying bacteria, being passed through filter-beds of gravel and charcoal, or other material, as coke-breeze, clinker, etc., the object of which is to provide an extensive surface for the growth of the micro-organism.

Before filtration, the sewage is screened to get rid of gross solid matter, and in many processes exposed to subsidence. It is sometimes thought desirable to prepare the sewage for the filter-bed by adding some precipitant which will throw down a proportion of the soapy and albuminous matters. Lime-salts, sulphate of iron, alum-refuse, or other chemicals, may be used for this purpose.

The *Bacterial Contact* process consists apparently of two stages: (1) The carbon oxidizing stage, in which the organic matters are attacked and converted into carbonic acid, water, ammonia, etc.; (2) the nitrification stage, in which the ammoniacal nitrogen is oxidized to nitric acid. It is necessary that the filter-beds should be so arranged as to allow a period of rest to each bed in turn, to obviate exhaustion of the bacteria.

The result of these processes, when properly carried out, is a clear, sparkling effluent, coming well within the standard of purity prescribed by the Rivers Pollution Commissioners, and which is said to be even potable.

Precipitation is still employed in many towns, either alone or in combination with other methods.

The points to keep in mind are: (*a*) The proportion of precipitants used; (*b*) the character of the precipitate likely to be obtained; (*c*) its disposal; (*d*) the character of the effluent.

The following are some of the principal processes:

The sewage is run into tanks, to allow subsidence of the matter in suspension, sometimes assisted by mechanical strainers ; but the effluent water is almost as dangerous as sewage itself, and requires purification before discharge into streams. It is usual to mix the fresh sewage before it runs into the settling-tanks with chemicals, as lime, alum, and iron, which may assist in the purification and perhaps disinfection of the sewage, but with most of them this is imperfectly done.

Lime-salts are useful in clarifying sewage, being good precipitants, but have little effect on the organic matter. If milk of lime be employed, the quantity necessary varies from 6 to 12 grains of quicklime to each gallon of sewage. It should be approximately adjusted to the amount of carbonic acid present in the sewage to be treated. If the effluent is made alkaline by the addition of too much lime, it rapidly undergoes putrefaction. It has been sought to remedy this by the addition of chloride of iron to the quicklime. This delays, but does not prevent, putrefaction. The effluent has little manurial value.

Aluminous substances form gelatinous compounds which carry down a quantity of matter in suspension.

Lime and *alum* enter into the composition of a number of processes.

The 'alumino ferric' process consists in using with lime or clay a cake of sulphate of alumina containing a small quantity of an iron salt.

A.B.C. Process.—The ingredients used practically consist of alum, charcoal, or refuse from prussiate of potash works, and clay. Blood is not now used. The clay and bulky alum precipitate carry down all the suspended matters, and the charcoal deodorizes.

Analyses show that, while all suspended matters are thrown down, the sludge also contains much phosphoric acid and ammonia. The effluent is purer than the standard. The sludge, when dried, is sold as native guano.

Black ash waste is the residue from the manufacture of washing-soda. It should contain sulphites and hyposulphites of lime. It has little precipitating power, but when mixed with a small proportion of lime it gives good

results. The effluent is almost free from odour, contains little organic matter, and shows no liability to undergo putrefactive change, as many effluents soon do.

Iron.—Various salts of iron are used. Ferrous sulphate of iron combined with lime is probably the most economical and efficient. The polarite (impure magnetic oxide of iron) and ferrozone (magnetic ferrous carbon) processes once enjoyed considerable vogue. These methods are costly and of doubtful efficiency.

Other chemicals, such as salts of zinc, manganese, and magnesia, have been used from time to time, but chiefly as deodorants. They are too expensive for general use.

Electricity has been suggested as a cheap and effective method of sewage purification. The sewage flows through a long channel, in which are a number of iron plates connected with a dynamo. These become so many electrodes. The positive plate becomes dissolved, and acts as a precipitant, while the water and some of the sodium chloride in the sewage are decomposed, nascent oxygen and hypochlorous acid resulting. The effluent is said to be clear and free from putrescible matter. The sludge is small in amount and inoffensive, consisting largely of hydrated ferric oxide.

Several of the above-mentioned methods are of little use when employed alone, but form useful adjuncts to other processes.

The effluent water from any of these processes cannot be allowed access to streams unless it comes up to some standard of purity. The Rivers Pollution Commissioners recommend that 100,000 parts of effluent water should not contain more than

2	parts	organic carbon	in solution.
0·3	,,	,, nitrogen	
3	,,	inorganic matter	in suspension.
1	,,	organic matter	

The Thames Conservancy Commissioners do not exact quite so high a standard.

Disposal of Sludge.—In precipitation by chemicals the average weight of sludge per million gallons is 20 tons,

and this contains about 90 per cent. of moisture. The following are some of the plans adopted or recommended for its disposal:

1. It may be deposited and spread out on land, and left to the influence of air, or it may be dug into the ground, or used as manure for roots, or as a dressing for wheat; or it may be

2. Mixed with road-sweepings, night-soil, and ashes for manure.

3. Dried on hot floor or by steam, forming a powder, or made into cakes by patent presses, and—

(*a*) Used as manure.
(*b*) Made into cement or bricks after burning.
(*c*) Used to raise low-lying ground.
(*d*) Used as fuel for furnaces.
(*e*) Thrown into the sea (London).

Sludge has slight manurial value, and as a rule fetches very little on sale. It contains perhaps 2 per cent. of the total organic matter of the sewage, but does not serve to any great extent as food for bacteria, because it has already been worked over by the organisms, and all matter available for food removed.

Purification of Effluent.—In most cases the purification of the effluent by filtration is essential. This may be accomplished on a small scale by *subsoil filtration.*

The system is carried out in this way: The whole of the household excreta, slops, etc., are allowed to flow into an automatic flushing-tank, and at periodical intervals this flush-tank discharges its contents into a drain which is impervious till it reaches the land in which it is to be utilized and purified; then pervious agricultural drains are laid, branching off the main at intervals, and the sewage percolates through into the soil. These drains are 2 inches in diameter, and ought to be laid at the depth of 1 foot. Before the sewage is allowed to enter the automatic flush-tank, it ought to pass through a strainer, so as to catch all solid material. This method does, of course, best in a porous, loamy soil, and the land must be under-drained. There should be ventilation between the house and the drain. The agricultural drain

must be taken up, cleansed, and relaid every one or two years.

On a larger scale either *intermittent downward filtration* or *broad irrigation* must be employed.

The Royal Commissioners on Metropolitan sewage discharge have given the following definition of these terms: 'Broad irrigation means the distribution of sewage over a large surface of agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied'; while in intermittent filtration 'the sewage is concentrated at short intervals, on an area of specially-chosen porous ground, as small as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a *sine quâ non*, even in suitably-constituted soils, whenever complete success is aimed at.

Intermittent downward filtration requires:

1. A porous soil, such as loose marl—containing oxide of iron and alum—sand, or chalk ploughed in furrows.

2. An effluent drain about 6 feet from the surface.

3. A proper fall of land to allow the sewage to spread evenly.

4. The division of the area into four parts; each part to receive sewage for six hours, and to have an interval of eighteen hours.

5. The land thus used as a sewage-filter requires constant aeration, not only by intermittent application, but also by being dug over or ploughed, else it will become 'sewage-sick'—*i.e.*, clogged up, and oxidation stopped.

Nitrification is the process of oxidation of animal matter which takes place in earth under the influence of living organisms. Ammonia, nitrites, nitrates, and fatty hydrocarbons are the result. The presence of gypsum (calcium sulphate) appears to facilitate the process by providing a base. Although these organisms may exist to a depth of 6 feet, yet nitrification is carried out chiefly at the surface, and in the upper 2 or 3 feet.

The amount of land required varies with the nature of the soil. On an average, an acre of good land will be sufficient for 1,000 people; but if precipitation is practised

first, an acre may do for from 3,000 to 5,000 of population. Crops should be grown on the land.

Average result of analysis shows that filtration removes 73 per cent. organic carbon, 87 per cent. organic nitrogen, and the whole of the suspended organic matter (P. F. Frankland). The effluent is very pure, and gives rise to no after-nuisance when allowed to flow into streams.

Irrigation.—The sewer-water, in as fresh a state as possible after being strained or precipitated, is distributed over the surface of cultivated land, with a view of bringing it as speedily as possible under the influence of growing plants, the purified liquid being carried off by natural or artificial drains.

The 'sewage-farm' should be on a gentle slope, and be intersected with trenches provided with dams, so that the water may be distributed as required. If a slope cannot be had, then artificial slopes must be constructed with a trench along the summit. The sewer-water should flow at the rate of 8 feet per hour. In winter the flow may be constant, so as to store up nourishment for plant-growth in spring; but when the plants are growing the flow is intermittent.

'Arrosage' is the term used when the sewage flows along furrows, not wetting the vegetables planted thereon.

'Colmatage' means that the whole surface is submerged.

The former is practised at Paris in summer, the latter in winter.

Land Required.—On an average an acre should be allowed for one hundred persons. Not more than £2 10s. per acre should be paid for rent (Bailey Denton). The site should be of easy access; there should be land available in case of increase of population, and an outlet for the sale of produce.

Results.—Suspended matters are arrested. Nitrification occurs. Chemical interchanges take place; thus, phosphoric acid joins with hydrated ferric oxide and alumina. Ammonia and potassium silicates with aluminium are formed by displacing calcium, which becomes a carbonate. These bases also form insoluble compounds with humus.

If the sewage be not strained first, and under-draining

not adopted, so that the effluent does not pass through the soil, but only over it, then the effluent will not be so pure as in downward filtration, which has advantage over irrigation in that, whereas a smaller area of land is exposed, the dangers to subsoil waters is diminished by careful under-drainage. But when sewage-farms are well managed and properly under-drained, so that filtration through it occurs, no nuisance should be created, nor should the ground become swampy; and it has not yet been shown that entozoic disease is more prevalent with this plan than with any other method.

Crops.—Italian rye-grass, osiers and roots, as mangold-wurzels, can be grown most successfully. Under certain circumstances market vegetables may also be planted. Cattle may be allowed with safety to graze on a sewage-farm. When the rainfall has been excessive, the sewage-water will be too dilute to apply to the land, so it is usually passed on to the river or sea without purification, unless a small part of the farm be reserved as a closely-drained filter for this purpose. Here the advantage of the 'separate' system is manifest. Even during severe frosts irrigation may continue uninterruptedly, the sewage having always a temperature well above the freezing-point.

Effluents may also be filtered through polarite or impure magnetic oxide of iron, one acre of which is sufficient for the purification of 5,000,000 gallons of sewage effluent daily.

2. Dry Methods.

The use of cesspools, privy-pits, dead-wells, etc., should be discontinued. If excreta are ever allowed to accumulate, it should be in properly-constructed non-porous receptacles. In No. 1 of the Model By-laws instructions are laid down as to how these places should be constructed. Earth-closets and dry privies should never be in a basement, but in a detached building, with thorough ventilation between it and the house. Both receptacle and closet should be ventilated to the outer air.

Earth.—The best kind for this purpose is vegetable or garden mould, taken from the surface of the ground. The excreta are deodorized, and organic matters disin-

tegrated. If the urine goes with fæces a larger amount of earth must be used ; modifications have therefore been made in the special closets (Moule's, etc.) to carry off the urine.

This process depends on bacterial action ; the earth, therefore, should not be dried over a stove, as it is thereby rendered sterile. It may have added to it a small quantity of ash, well screened from cinders, which affords a base for the action of the nitrifying bacteria.

Charcoal may be cheaply used in the shape of peat or seaweed charcoal, 3 ounces being used for each dejection. Both fæces and urine may pass into the same receptacle ; the mixture can be recarbonized in a retort, and the carbon used again. The distilled products (ammoniacal liquor, containing acetate of lime, tar, etc.) which result are sufficient to pay the cost of the process.

Peat-dust is not only absorptive and rapidly deodorant, but has distinct destructive action upon cholera and typhoid bacilli.

Deodorant Powders.—Instead of earth and charcoal, powders and sawdust, containing various disinfectants, are in use. These are too expensive for ordinary use, and, moreover, the presence of disinfectants destroys the manurial value of the product.

The Pail System.—In the poorer parts of many towns this system is in use. Each family is provided with a pail, having a close-fitting lid ; into this all excreta and generally other refuse are placed. The pails must be emptied daily. Sometimes the pails are lined with cloth refuse (Salford, etc.), or with straw, peat, etc. (Goux's patent); the fæcal matter is thus rendered drier by the absorption of the urine, and decomposition is delayed.

Disposal of the Contents of the Receptacles.—They may be at once applied to land as manure ; when this cannot be done, they may be dried and converted into manure as a powder, or they may be carbonized, or burnt.

To obtain the utmost value from the contents of earth-closets or privies they must be regularly removed, and deposited in a shallow trench in well-tilled land. The nitrifying organisms, which are most numerous in the upper layers, at once attack the filth, and convert it rapidly and inoffensively into vegetable mould, in which,

after four days, cabbages may be planted and successfully grown. Where no earth is used the pails should be emptied daily; where suitable earth is employed the nitrifying process begins in the pails.

In India shallow trenches are dug in a field, and earth thrown over the excreta directly deposited in them. When the trenches are full the whole is ploughed up, and vegetables at once planted. Two or three crops are taken before that ground is again used.

It has been suggested that house refuse should be treated with weak sulphuric acid absorbed in fine ashes; the volatile ammonium compounds are fixed by conversion into sulphate, and there results a more or less highly nitrogenous manure, which can be sold at about 1s. 6d. a ton. Practical experiments with this substance have proved it to be a valuable fertilizer.

All the dry methods require some arrangement to carry off rain-water, slop-water, etc. For small places 'sub-irrigation,' already mentioned, has been proposed; but if only house waste-water has to be dealt with, it would be better to run it on to the surface along a field-tile drain, so that it comes at once into contact with the most active part of the earth. In larger places, where houses are closer together, the waste-water must either be conveyed away by drains under the ground, or, as recommended by Dr. Vivian Poore, on the surface freely open, so that no stagnation occurs. In either case the waste-water may be applied to the soil.

Cesspools.—When a cesspool *must* be provided it should be rendered perfectly water-tight; it must not be nearer any house or work-place, or any well, spring, or stream of water, than 100 feet; it must not have an overflow, outlet, or any communication with any drain; it must be covered over, adequately ventilated, and readily accessible for purposes of cleansing. A cesspool must be so situated that it may be emptied without the contents having to be carried through any living or work premises.

Liernur's pneumatic air plan is employed in Holland. The excreta fall into a pipe, from which they are extracted by exhaustion of the air by an air-pump. The pipes are never clean, but become lined with decomposing fæces. A separate arrangement is required for rain and slop water.

Choice of Method for Disposal of Excreta.

This depends largely upon the circumstances of the locality. For large communities the water-sewage plan (with or without interception of rainfall) appears to be the best, but an adequate water-supply is a necessary condition. A sufficient fall is also requisite ; but the use of Shone's ejectors will obviate local difficulties of fall, though, of course, adding greatly to the expense of a water-carriage system.

Much also depends upon the character of the waste-water to be dealt with, as if this contains factory effluents of varying qualities it will not be suitable for immediate application to land.

For villages and small towns the water system is, as a rule, too expensive.

Cleansing of Towns.

Disposal of House-refuse.—The old system of dust-bins, ash-pits, or middens is gradually giving place to one in which the house-refuse is daily removed from pails.

The practice of levelling up low-lying land, brick-fields, old quarries, etc., with the refuse is not to be recommended, unless the material has been burnt.

At Rochdale the ashes and excreta are mixed and dried and used as manure.

At Manchester the coarser part of the rubbish and the cinders are burnt under boilers, etc.; the clinkers resulting are ground into powder, and used for making mortar.

Soap and oil are extracted from bodies of dead animals.

In many towns there is considerable difficulty in getting rid of the refuse either on land or in the sea ; recourse has therefore been had to carbonizing or to burning it in 'Destructors,' which, with care in stoking and cleansing, can be used without causing nuisance. Offensive smells are prevented by the use of an additional furnace called a 'fume cremator,' which destroys all gases passing from the destructor ; or, more economically, by raising the temperature by means of the forced blast, and securing that

all vapours are thoroughly exposed to the heat. To obtain the most satisfactory results refuse should first be sorted, so that incombustible materials may be removed. The resulting clinker may be used for concrete, tar-paving, mortar, artificial stone-making for buildings or pavements, road-making, etc. The heat evolved may also be used to drive electric motors or other engines. The fine dust obtained from the flues has been mixed with carbolic acid, and made into disinfecting powder.

Street-sweepings may be utilized as manure or burnt in the destructor. When very liquid, the excessive moisture should be allowed to drain off first. When the contents of street-gullies are removed, they should be well covered over with some disinfecting powder.

Courts, alleys, urinals, etc., should be properly paved with some impervious material, so that they can be washed with the hose regularly and frequently.

For street-watering sea-water may be used, as at Hastings, Portsmouth, etc. It binds the surface of the roads, and they require a third less frequent watering, as they remain damp longer than with fresh-water. In the more crowded districts of a town, or when an epidemic has broken out, the addition of 'Sanitas' to the water is beneficial and refreshing.

After falls of snow, gutters and gullies should be cleared, else flooding of houses might ensue if a thaw set in.

From a hygienic standpoint, asphalte is the best material for paving streets, as being most easily cleansed. Wood pavements, especially if made with uncreasoted wood, may become offensive in hot weather, and it is advisable to water such with water containing some oxidizing deodorant, as crude 'Sanitas' or permanganate of potash. In point of safety, fewest accidents are said to occur on wood, most on asphalte.

CHAPTER IV.

AIR AND VENTILATION.

Air.

THE average composition of atmospheric air is :

Oxygen, 209·6 per 1,000 volumes.
Nitrogen, 790·0 per 1,000 volumes.
Carbonic acid (carbon dioxide), 0·4 per 1,000 volumes.
Watery vapour, varies with temperature from 1 to 12 grains per cubic foot of air.
Ammonia, traces.
Organic matter (in vapour or suspended, organized or unorganized, dead or living), traces.
Ozone, variable.
Sodium and other mineral salts, variable.

Professor Armand Gautier has recently discovered that pure atmospheric air contains free hydrogen to the extent of 2 volumes per 10,000.

The above table gives the average composition, but the oxygen may reach 209·8 in pure mountain air, or fall to 208·7 in towns. By weight 23 per cent. is oxygen.

IMPURITIES.

The carbonic dioxide and other impurities are derived from the products of respiration, combustion, manufactures, the decomposition of organic matters, etc. The air is, however, kept in a state of purity by natural processes, mechanical and chemical. Of these the chief are diffusion, dilution by winds, oxidation, the fall of rain washing down and dissolving both gases and solids, and the influence of plant-life.

The **suspended matters** are : Silica, silicate of alumina, carbonate and phosphate of calcium, and peroxide of iron from the soil; carbon, sand, and fine mud from volcanoes.

Seeds and débris of vegetation, pollen, spores of fungi, mycoderms, mucedines, germs of vibriones, monads, and other micro-organisms ; various forms of minute animal life, alive and dead.

Chloride of sodium derived from the sea in spray.

Dried excreta, etc., of man and animals.

In inhabited rooms there may be found epithelium, fibres of clothing, portions of food, hair, wood, coal, arsenic (from wall-papers), while in sick-rooms organic matter is in large quantity with epithelium and pus-cells, bacilli and fungi.

In workshops, factories, and mines, dust from the fabrics and materials pass into the air.

CO CO_2 CH_4

The **gaseous impurities** are : Carbon dioxide, carbon monoxide, and carburetted hydrogen or methane.

Sulphur dioxide, sulphuric acid, hydrogen and ammonium sulphide, and carbon disulphide.

Hydrochloric acid (from alkali works).

Ammonia, ammonium acetate, sulphide and carbonate, nitrous and nitric acids.

Hydrogen phosphide.

Ogranic vapours from decomposing animal matters.

Respiration is responsible for the following : Oxygen is decreased, carbonic dioxide is increased, watery vapour with ammonia and organic matters is produced.

Carbonic Dioxide.—An adult man, weighing 12 stone, in a state of repose, will give off about 0·72 cubic feet per hour, mostly from the lungs, but partly from the skin. This amount varies proportionately with the body weight. Women, children, and old people, give off less CO_2. The amount is increased by exertion in this proportion : In repose, 2 ; in gentle exercise, 3 ; in hard work, 6 (Pettenkofer).

Average amount of CO_2 per hour per person in a mixed community is 0·6 of a cubic foot, equal to about 8 ounces of carbon in twenty-four hours.

Expired air contains oxygen 169·6, nitrogen 790, and carbonic acid 40·4 parts per 1,000.

Amount of air daily taken into the lungs by a man is estimated at 400 cubic feet, 30 cubic inches per respiration.

Moisture with Organic Matter.—Twenty-five to forty ounces of water pass off daily by the skin and lungs, requiring on an average 211 cubic feet of air per hour to maintain it in a state of vapour.

The *organic matter* is the most important impurity resulting from respiration. It consists partly of suspended matter, epithelium, etc., and partly of fœtid substances containing ammonia and sulphur in their composition. It is slowly oxidizable. When drawn through sulphuric acid it darkens it; permanganate of potash solution is decolorized by it. When collected from the air, mixed with pure water, nitrate of silver causes a precipitate; heated on platinum foil, it chars.

It has a great affinity for water, and is readily absorbed by damp walls. It is deposited on furniture and clothing, straw and horsehair absorbing least, white and yellow bodies taking less than black and blue. It is this which gives the feeling of closeness to ill-ventilated rooms.

The amount of organic matter is in proportion to the CO_2 present, which, being easily determinable, is taken as a measure of the organic impurity due to respiration. Thus, when CO_2 reaches 0·6 per 1,000 volumes, the organic matter can readily be detected by the sense of smell.

Combustion.—The air within dwellings is contaminated by the products of lighting and heating. *Coal*, when burnt, yields:

Water.	
Fine carbon and Tarry particles	1 per cent. of its weight.
Carbon dioxide, about 3 tons for each ton of coal.	
Carbon monoxide	Depends on the perfection of combustion. Usually a small quantity, larger with anthracite coal.
Sulphur, sulphur dioxide, and sulphuric acid	Coal contains ½ to 7 per cent.
Carbon disulphide Ammonium sulphide or carbonate Hydrogen sulphide (sometimes)	Chiefly from certain kinds of factories.

For complete combustion, 1 pound of coal requires about 240 cubic feet of air.

Coal-gas has an average composition of:

	In 100 Parts.
Hydrogen	45
Light carburetted hydrogen (CH_4) ...	38
Carbon monoxide	4·5
Olefiant gas (ethylene, C_2H_4)	3·5
Acetylene (ethine, C_2H_2)	2·5
Hydrogen sulphide	0·5
Nitrogen	2
Carbon dioxide	3
Sulphur dioxide	0·5
Ammonium sulphide	traces.
Carbon disulphide	traces.

Gas is purified before leaving the works by washing to remove tar. It is then dried and passed over lime or sesqui-oxide of iron to take away hydrogen and ammonium sulphides, carbon disulphide, and other impurities. Nuisance often arises in the neighbourhood of gasworks from the effluvia given off by the lime when the tanks are emptied. This may be obviated by drawing air through the tanks before emptying, in order to remove the gases in a free state. If this be not done thoroughly, these impurities will be passed into the air of the rooms in which the gas is used.

The value of coal-gas as regards its illuminating power is ascertained by comparing the light given off by gas burning at the rate of 5 cubic feet per hour with that of a sperm candle burning 120 grains per hour. Thus, cannel-coal-gas is said to be equal to 34·4 candles, and gas from common coal to thirteen candles (Roscoe).

The constituents of coal-gas are divided into *diluents* (hydrogen and marsh gas), *illuminants* (olefiant gas, acetylene, and other hydrocarbons rich in carbon), and *impurities* (nitrogen, carbon dioxide, sulphur compounds, etc.).

Sulphur, according to Act of Parliament, must not exceed 20 grains per 100 cubic feet. Ammonia should not exceed 4 grains per 100 cubic feet.

In ordinary combustion, the following products escape into the air :

Nitrogen	67 per cent.
Water	16 ,,
Carbon dioxide	7 ,,
Sulphur dioxide	small quantities.
Ammonia	,, ,,

Carbon monoxide, 0·5 per cent. ; but with perfect combustion, none.

One cubic foot of gas unites with from 0·9 to 1·64 cubic feet of oxygen (8 cubic feet of air), producing 2 cubic feet of carbon dioxide, and from 0·2 to 0·5 grains of sulphur dioxide. Various plans are adopted to render the combustions more perfect, as the use of the Argand and Siemens burners, of the Welsbach incandescent burner, the addition of naphthaline (albo-carbon), and the adoption of regulators on the pipes so that the pressure may be constant.

One cubic foot of gas will raise the temperature of 31,290 cubic feet of air 1° F.

Wood produces carbon dioxide and monoxide and water, and requires about 120 cubic feet of air for the complete combustion of 1 pound.

Oil.—One pound requires 140 to 160 cubic feet of air for complete combustion ; 150 grains of oil, or 170 grains of candle, are burnt per hour, consuming the oxygen of about 3·2 cubic feet of air, and producing about ½ cubic foot of CO_2.

Tobacco smoke contains much carbon dioxide, ammonia, and butyric acid, with salts of nicotine and probably of picoline. In smoking-cars Dr. Ripley Nichols found four or five times more ammonia than in external air.

Water-Gas.—This gas is produced by passing steam through coals at a red heat, and the consequence is that after purification hydrogen only remains. This mixture is very inflammable, and while burning gives out a very great heat, but it is not capable by itself of yielding much luminosity. It can be used for heating and cooking, and would be suitable for use with incandescent burners. On combustion, watery vapour only is formed. In the pro-

cess of manufacture carbon monoxide is produced, and precautions must be taken to prevent the workmen inhaling it.

Effects Produced by the Products of Combustion passing into the Air.

Carbon dioxide soon becomes diffused.

Suspended carbon and tarry matters, as a rule, are not found at a higher altitude than 600 feet. Smoke from houses, even in large towns, does not appear to affect the atmosphere so much as that given off by factories, foundries, etc. Compare the condition in this respect of Lancashire manufacturing towns with non-manufacturing towns, or West with East London. The organic mat'er in the air is increased by the combustion of coal and by oil lamps. But the most noxious contaminations derived from coal are the hydrochloric, sulphurous, and sulphuric acids, which in many manufacturing towns render the air distinctly acid (Angus Smith, Fletcher, and others). To the presence of these acids is ascribed the deleterious influence of coal-smoke upon vegetation.

Smoke Abatement.—Section 91 of the Public Health Act, 1875, defines as a nuisance any fireplace or furnace which does not as far as practicable consume the smoke arising from the combustible used therein, and which is used in any manufacturing process whatsoever. The same section provides that the court to which an appeal may be taken shall dismiss the complaint if it is satisfied that such furnace is constructed in such a manner as to consume its smoke as far as practicable; but when any chimney, not being the chimney of a private dwelling-house, is sending forth *black smoke* in such a quantity as to be a nuisance, it is not necessary to prove, in order to secure a conviction, that the furnace is improperly constructed or inefficiently tended. A conviction must follow the proof of the emission of 'black smoke in such quantity as to be a nuisance.' In the provinces local authorities often, from interested motives, allow this clause to become a dead letter.

In London, Section 23 of the Public Health (London) Act, 1891, is even more stringent, and it is laid upon the metropolitan sanitary authorities as a distinct duty to

carry out this twenty-third section, and, moreover, an information under the section is not to be laid except under the direction of a sanitary authority.

The section applies also to the Port of London, and is to be enforced by the Port Sanitary Authority.

Steam vessels on the river Thames are compelled to consume their own smoke under penalties. Locomotive steam engines used on railways (Railway Regulation Act, 1868), and also locomotives and traction engines on the highroad (Highways and Locomotives Acts, 1878), must be so constructed as to consume as far as practicable their own smoke.

In London and other large towns special sanitary inspectors are often entrusted with the special duty of detecting smoke nuisances, and obtain evidence by means of photography.

In order to prevent black smoke from furnaces, Mr. Alfred E. Fletcher points out that three conditions must be observed:

1. There must be a sufficiency of air.
2. The air must be well mixed with the fuel.
3. This mixture must be raised to the temperature necessary for ignition.

Besides the numerous contrivances for carrying out these conditions, there have been invented mechanical stokers, whereby the fuel is regularly and continuously supplied.

Numerous plans have been suggested for dealing with smoke from private houses, such as the use of gas, slow combustion stoves, heating by means of hot air, the use of 'smokeless' (anthracite) coal, and various contrivances in open grates (Siemens, Teale, etc.).

Frankland recommends throttling the chimney-mouth, and the use of coke broken small.

Effects Produced by Impurities in the Air.

By Suspended Solid Matters.—Under this head are included diseases due to:

1. Various unhealthy occupations.
2. Living substances, as fungi, algæ, pollen, etc.
3. Specific contagia.

1. **Unhealthy Occupations** affect the health chiefly by means of *dust*, and the subject may be conveniently considered here. Dr. Arlidge, in the Milroy Lectures (1889, 'Occupations and Trade in Relation to Public Health'), has divided the conditions causative of disease thus:

(1) Generation of dust $\begin{cases} \text{Poisonous.} \\ \text{Non-poisonous.} \\ \text{With heat and moisture.} \end{cases}$

(2) Employment of materials of a distinctly poisonous or highly noxious nature.

(3) Evolution of poisonous or injurious vapour.

(4) Excessive temperature.

(5) Evolution of electricity.

(6) Abnormal atmospheric pressure.

(7) Circumstances affecting special senses.

(8) Excessive use, friction or strain on parts of the body.

(9) Exposure to infectious, contagious, or parasitic diseases.

(10) Extra liability to accidents.

Besides, there are the more general conditions of situation and construction of factory, etc.; the soil, climate, population, etc.

Dust produces respiratory diseases, such as frequently recurring catarrhs (with or without expectoration), bronchitis, followed sometimes by emphysema, in acute pneumonia, asthma, and chronic non-tubercular phthisis, as well as, in many instances, tubercular disease of the lungs. This is well shown by Dr. Ogle in his supplement to the forty-fifth annual report of the Registrar-General, where he gives the table printed on p. 81.

The digestive organs are affected only to a slight extent.

The suspended matters may be mineral, vegetable, or animal. According to Parkes, the severity of the effects is chiefly dependent on the amount of dust, and on the physical conditions as to angularity, roughness, or smoothness of the particles, and not on the nature of the substances, except in some special cases; while Dr. Arlidge states that earthy and metallic dusts are more provocative of lung disablement than organic dust, with the exception of charcoal; but then it is inorganic dusts and charcoal

Comparative Mortality of Males, Twenty-five to Sixty-five Years of Age, in certain Dust-inhaling Occupations, from Phthisis and Diseases of the Respiratory Organs.

Occupation.	Phthisis.	Diseases of the Respiratory Organs.	Phthisis and Diseases of the Respiratory Organs.
Coal-miner	126	202	328
Carpenter, joiner	204	133	337
Baker, confectioner	212	186	398
Plumber, painter, glazier	246	185	431
Mason, builder, bricklayer	252	201	453
Wool manufacturer	257	205	462
Cotton manufacturer	272	271	543
Quarryman (stone, slate)	308	274	582
Cutler	371	389	760
File-maker	433	350	783
Earthenware manufacturer	473	645	1,118
Cornish miner (tin)	690	458	1,148
All males (England and Wales)	220	182	402
Fishermen	108	90	198

that possess those physical characters which tend to produce the more severe effects.

Miners of all kinds suffer from an excess of pulmonary disease caused by the inhalation of dust which is produced by their work, but coal-miners suffer less in this respect than other workers in mines. The air of mines is rendered impure also by respiration, combustion from lights and from blasting operations, and from the escape of fire-damp (CH_4) and carbonic dioxide from cavities in the rocks. Loss of life after fire-damp explosions is said to be due rather to the absence of oxygen than the presence of carbonic acid. When gunpowder is used, carbon dioxide and monoxide, hydrogen, and hydrogen sulphide are added to the air, with suspended particles of potassium sulphate, carbonate, hyposulphite, sulphide, sulphocyanide and nitrate, carbon, sulphur, and ammonia carbonate. Dynamite and gun-cotton add nitrous fumes to the air, but no carbon monoxide or hydrogen sulphide. The use of roburite (chloro-dinitro-benzol and nitrate of ammonia) seems likely to take the place of other agents for shot-firing in mines, as carbon dioxide to a small amount is the chief impurity, and there is an absence of smoke.

Prevention of disease arising in connection with mines depends in a great measure upon the thoroughness of the ventilation. As better ventilation has been introduced into collieries, the 'coal-miner's lung' has become a less frequently seen pathological specimen. The following list includes most of the trades which affect workmen injuriously by means of dust:

Corn-millers and bakers, maltsters, tea-men, coffee-roasters, snuff-makers, paper-makers, flock-dressers, shoddy-grinders, coverlet and harding weavers; dressers of hair, of coloured leather, of hemp; workers in flax, cotton, wool, and silk; some workers in wood; wire-grinders, masons, colliers, iron-miners, lead-miners, grinders of metals (especially of the finer tools), file-cutters, firearm-makers, button-makers (especially mother-of-pearl), emery-wheel workers, potters, china scourers, electro-plate workers; grinding-stone, sandpaper, and glass makers; cement and poudrette makers, workers with arsenic and lead, drug and colour grinders and mixers, etc.

In all these trades good ventilation, regulation of temperature, and personal cleanliness diminish the evil to a great extent; but additional contrivances have been suggested to suit the varied requirements of the different kinds of labour. Thus, wheel-boxes, ventilated by fans, and the wearing of coverings for the mouth and nose, such as Loeb's respirator, may be employed. This form of respirator enables the wearer to breathe comfortably in an atmosphere full of dust, noxious gases, or dense smoke.

The use of fans in grinding operations not only protects the lungs, but also tends to lessen the risk of injuries to the eyes.

Wet-grinding is attended with less evolution of irritant dust than dry-grinding, but the stones are constantly throwing off water, which soddens the floor and saturates the air of the room. The want of ventilation, combined with this dampness and the stooping over the wheels, tends to produce chest affections.

In the manufacture of super-phosphates, in addition to the dust, there is danger from the vapour of silicon fluoride, which causes a gelatinous deposit on the mucous membrane of the air-passages, producing suffocation (C. A. Cameron).

Bichromate of potash dust causes irritation, ulceration, and destruction of both the mucous membrane and bones of the nose. The taking of snuff partially obviates these results by removing the particles from the nose. The fluids of the mouth dissolve and get rid of the salt, but the skin is apt to have sores produced unless washed with subacetate of lead.

Wood-dusts act as irritants in proportion to their density. Ebony and rosewood dusts produce bronchial troubles, and it is said the latter may cause eczema.

Of *textile* manufactures, that of *flax* produces more dyspnœa than is caused by any other dust not actually poisonous.

In the manufacture of the best *silk* disease is not caused, but follows on the preparation for trade purposes of inferior silk and silk waste. In the 'gassing-rooms' the air is rendered additionally impure from the gas and from the scorching of the silk particles. The temperature is high —90° to 120° F. The use of Bunsen burners would be an improvement.

Persons engaged in the manufacture of wool are exposed not only to the risks engendered by ordinary dust, in proportion to the dryness of the wool, but to the danger of contracting wool-sorter's disease from wools specifically infected with the spores of anthrax. This danger is especially attached to imported wools, particularly from the neighbourhood of Lake Van in Armenia and from Persia. Imported wools, and indeed all wools, should be submitted to preliminary disinfection or washing; sorting-rooms should be well ventilated and lime-washed at regular intervals; fan-beats should be used to carry away the dust generated during the opening and sorting of bales; and workmen should be made to wash their hands before eating and change their clothes after work.

'Shoddy disease'—headache, sickness, dryness of mouth, difficulty of breathing, cough and expectoration (Greenhow)—sometimes occurs in those engaged in the tearing up and grinding of old woollen materials.

In connection with the *cotton* trade there is dust of various kinds present in the different processes, and its removal is rendered difficult, as the cotton is very susceptible to variations in the atmospheres of the rooms. Inlet tubes and fans, extracting the air and dust by suction, are generally used.

Cotton Weaving.—During the American Civil War, when cotton was scarce, manufacturers resorted to the expedient of sizing the yarn to bring the fabric up to the required weight, and have not since given up the practice. Sized goods are in demand in warm countries, where their stiffness appears to be appreciated. The difficulty is to keep the sizing (which consists of tallow, flour, and china clay) on the yarn while it is being woven; this has been overcome by allowing steam to escape over the workpeople's heads, so as to keep the fabric moist. The atmosphere is further vitiated by the use of gas in winter. The operatives, who are mostly women and children, get their clothing saturated with the moisture, and on going out of the hot rooms are liable to rheumatism, bronchitis, etc. An escape for air is usually provided near the ridge of each roof, but this gets blocked up in winter, and is rarely reopened. As only a small quantity of steam is required, it might be possible to have its admission, etc.,

regulated in such a manner as would not be injurious to health, as by introducing the steam immediately below the weft ; while the use of the electric light might advantageously supersede gas.

Chimney-sweeps used to suffer from cancer due to the irritation of the soot, but this is not so common now that climbing up the chimneys has been done away with. Workers in petroleum and tar are said to be similarly affected.

Match-makers, who are exposed to the fumes of white *phosphorus*, suffer from necrosis of the jaw. This may be obviated by the use of red amorphous phosphorus, coupled with free ventilation of workshops.

Brass founders suffer from 'brass-founders' ague,' characterized by feelings of tightness and oppression of the chest, with shiverings, headache, nausea, and muscular pains, an indistinct hot stage and profuse sweating. The attacks are not periodical, but are more frequent in foggy weather and in ill-ventilated shops. The workmen are also subject to various nervous disorders. There is a difference of opinion as to the cause. Some assert it to be due to the fumes of zinc oxide, but it is more probably due to copper poisoning, as coppersmiths are similarly affected. A green line is generally to be seen on the gums of the lower jaw. Large draughts of milk are believed to lessen the severity of the attacks.

Meals should not be allowed to be taken in the casting shops. Thorough ventilation and frequent cleansing of the premises, as well as personal cleanliness on the part of the workmen, should be enforced.

Persons working with lead are liable to absorb it into their systems, and may suffer from lead-poisoning, characterized by tightness at the chest, nausea, twisting pain at the umbilicus, anæmia or nervous affections, weakness and trembling of the muscles of the arm, especially of the extensors of the wrist and fingers, neuralgic pains often in muscles, epilepsy, weakness of intellect, etc. Women exposed to lead-poisoning are liable to repeated abortions. There is a blue line on the edge of the gums due to sulphide of lead.

Operatives specially exposed to risk of lead-poisoning are those employed in the manufacture of white and red

lead, plumbers, painters, and persons engaged in the following industrial occupations: Varnishing of leather, and the imparting of a glaze to visiting and playing cards; the making of artificial flowers, leaves, and jewels; the weighting and dyeing of silk and alpaca; the preparation of lace and straw hats; the preparation of paints; calico printing and dyeing; the glazing of pottery, bricks, etc.; the enamelling of iron plates and hollow ware; file-cutting, glass-cutting, type-founding, and type-setting (Notter and Firth).

Lead-mining involves no special risk of lead-poisoning, but during the smelting of the ore vapourized lead is given off, together with fumes of sulphur dioxide. The risks attending on smelting may be obviated by the use of condensing chambers and water in the form of steam or shower baths.

File-cutting by hand is done by cutting the file with a chisel and hammer on a lead block. Much lead-dust arises in the process. File-cutting is now done by machinery. Glass grinders may be poisoned by constant contact with fine glass-powder, which is rich in lead. Sulphide of lead is used in the glazing of bricks and pottery. The attention of Parliament has recently been devoted to this subject. It is contended by some that leadless glaze can be used in pottery, which is equally as good as lead glaze. Lead enters into the composition of many dyes and pigments.

Much dust is produced in the manufacture of red lead, but the manufacture involving the most deadly risks of lead-poisoning is that of white lead. Three processes are in use: (1) Thenards, by which the carbonate is developed directly by the action of carbon dioxide on the lead; (2) the Birmingham method, in which the carbon dioxide is evolved by the combustion of coke; (3) the Dutch method, in which acetic acid is slowly volatilized in pots, on the top of which thin sheets of lead are placed. Subacetate of lead is formed, which is again decomposed by carbon dioxide, evolved from quantities of tan (Notter and Firth). The sheets from the 'stacks' are then removed, and directly handled by women and girls. The Dutch method is the one most commonly employed, and by far the most dangerous. A Departmental Committee

presented to the House of Commons in 1893 an important report on the conditions under which lead and its compounds are produced. They recommended that females (who are specially susceptible to lead-poisoning) be excluded from all direct contact with white lead; that no female under twenty should be employed in white-lead works; that before employment women should be submitted to medical examination; and that in both sexes a medical certificate should be required after absence through illness before return to work.

Only a recommendation

It is proposed that in colour works the employment of females and male 'young persons' should be prohibited, and that in lead smelting these two classes should not be permitted to clean the flues; further, that nobody should be allowed to work in the flues for more than two hours at a time, nor leave afterwards before taking a bath. The provision of special lavatory accommodation is advised in colour works, lead smelting, turning and enamelling of iron hollow ware, electric accumulator, and red and orange lead works; and in the last it is recommended that all persons employed should be submitted to a weekly medical inspection. In the case of white lead and the enamelling of iron plates and hollow ware, the provision of a dining-room is recommended. Overalls should be worn by the operatives while at work; no food should be allowed to be eaten in the workshops; frequent washing of hands and clothes should be ordained; and the use of drinks containing dilute sulphuric acid encouraged.

The use of white sulphate of lead or of oxide of zinc have been proposed as pigments in substitution for carbonate of lead, but it is contended by those interested that they are not only more costly but inferior as pigments.

Workers in *mercury*, mirror silverers, etc., may get salivated with general cachexia, headache, numbness and unsteadiness, beginning in hands and arms and spreading to the rest of the system.

Preventive Measures.—Work to be done in well-ventilated rooms; cleanliness; no food should be eaten in workrooms. Mirrors can be made with nitrate of silver.

Operatives employed in 'felting' fur for hats are liable to erosion of the gums, loss of teeth, and general

anæmia from poisoning by acid nitrate of mercury, which is used in solution in the process, and is conveyed by the dust of the factory.

Arsenical poisoning may result in those who use compounds of arsenic, as in the making of wall-papers, etc., or who have inhaled the dust of rooms papered with arsenical papers. The effects are both local and constitutional, the local being smarting of the gums, eyes, nose, œdema of the eyelids, and little ulcers on exposed parts of the body; the constitutional being weakness, faintness, asthma, anorexia, thirst, diarrhœa, and sometimes severe nervous symptoms, especially neuritis. In bone manure factories it has been shown that arsenic is given off in considerable quantity; this is due to the use of impure sulphuric acid. This also occurs in copper smelting.

In 1901 an extensive epidemic of arsenical poisoning, characterized chiefly by neuritis, occurred among beer-drinkers in Manchester and other towns. The subject was investigated by a Royal Commission, and the arsenical poisoning traced to the use of impure sulphuric acid in the manufacture of glucose, which is now largely employed in brewing. The epidemic was attributable chiefly to the glucose issued by a particular firm. The use of pure sulphuric acid obviates this danger.

Effects of Intense Light and Heat.—Mr. Simeon Snell and others have drawn attention to the effects of intense light and heat on the eyes of persons employed in certain trade processes.

Glass-blowers, electric welders, stokers, and puddlers, may suffer from impairment of vision, pain, photophobia, choroidal changes, slow atrophy of the optic nerve, and cataract. The burnishing of electro and silver goods, as pursued in Sheffield trades, has been found to produce retinal hyperæsthesia in the females usually employed at this work.

2. **Living Substances or their Germs, or Pollen of Flowers.**—Hay-fever, or summer catarrh by the pollen from grasses (especially *Anthoxanthum odoratum*), trees (especially lime), or flowers. Nausea, fainting, and giddiness are produced by *Chætonium elatum* (bristle mould), and the spore of penicillium, when inhaled, has produced hoarseness and aphonia with catarrh.

Tinea and favus may be spread by air.

The examination of air has been carried out for some years very methodically by Dr. Miguel at the Observatory of Montsouris in Paris. He found that fungoid spores were more plentiful in the air in hot weather than in cold. Bacteria of various kinds were always present in Paris; at an altitude of from 2,000 to 4,000 metres on the Alps no microbes were found; as he descended the number gradually increased until 760 microbes per cubic metre were found in the park at Montsouris, and 5,500 in the Rue de Rivoli. In hospitals, Miguel reports that in winter, when the windows are kept shut, the greatest number of microbes is to be found, which is the reverse of the condition obtaining in the open air.

In this country the presence of microbes in houses, schools, etc., has been demonstrated by Carnelley and others, and they have shown the improvement that can be produced by proper ventilation. In houses the number of microbes increases in proportion as the living rooms decrease in size, and according to how many rooms constitute a house; thus, a one-roomed house contains more microbes than a two-roomed house, and sickness and mortality go *pari passu*.

That the following diseases reach the person through the medium of the air cannot be doubted—viz., tuberculosis, scarlet fever, small-pox, measles, typhus, pertussis, diphtheria, influenza, purulent and granular ophthalmia, erysipelas, hospital gangrene, etc. In these cases the disease poisons are living organisms or their spores, which exist separately or in epithelium, pus cells, or other disintegrating organic material (see chapter on Communicable Diseases).

Effects produced by Gaseous Matters in the Air.

Carbon dioxide produces fatal results when the amount reaches from 50 to 100 parts per 1,000; 15 to 20 per 1,000 produces headache, giddiness, and even faintness. Living continuously in an atmosphere heavily charged with CO_2 may, by preventing its elimination from the blood, produce serious alterations in nutrition, but in crowded localities

the organic matter present is probably the more active agent.

Acute poisoning causes sudden loss of consciousness, the blood becomes of a dark hue; a person so affected by CO_2 should be immediately removed to purer air.

Carbon Monoxide (CO).—Less than $\frac{1}{2}$ per cent. has produced symptoms of poisoning, 1 per cent. is fatal. Poisoning thereby is characterized by unconsciousness, destruction of reflex action, atony of vessels, diminution of vascular pressure, slowness of circulation, and, finally, paralysis of the heart. At high temperatures there may be convulsions. The blood is of a florid red colour (more of a chocolate red than ordinary arterial blood), due to the formation of a compound of CO and hæmoglobin more stable than oxyhæmoglobin; blood exhibits a special and characteristic spectrum. Fresh air does no good, as the the oxygen cannot displace the CO from the compound; it is possible that the CO may be converted into CO_2, and so got rid of; but transfusion is the best treatment. CO is evolved with CO_2, and H_2S in brickfields and cement works.

It is produced by the imperfect combustion of coal-gas, coke, or coal. It is frequently present in considerable quantities in furnace flues, and may pass through cast-iron stoves when red hot. Several deaths from carbon monoxide have occurred from the use of 'Geyser' heating apparatus in unventilated bath-rooms.

Hydrogen sulphide (H_2S).—Men who are exposed to large quantities of sulphuretted hydrogen suffer from weakness, anorexia, slow pulse, furred tongue, face and mucous membrane pale; sometimes there are boils on the body, sometimes vertigo, headache, nausea, diarrhœa. There are great differences of susceptibility; some are quite unaffected. Acute poisoning also occurs either in a narcotic or in a convulsive form. Dogs and horses are more affected than are men.

Hydrogen sulphide is evolved in chemical works (e pecially ammonia); Britannia metal works; in tunnels and mines (from the decomposition of iron pyrites).

Ammoniacal vapours produce irritation of the mucous surfaces with which they come in contact—the conjunctiva suffers most.

Sulphur dioxide (SO_2) is evolved in copper-smelting works, and in the bleaching operations in cotton and worsted factories. It produces anæmia and bronchitis if in considerable amount. When washed down by the rain it affects cattle through the herbage, producing affection of the bones, falling off of the hair, and emaciation.

Hydrochloric acid vapours in large quantities are very irritating to the lungs, and they destroy vegetation even when diluted to one-fifth grain in each cubic foot of air, gas, or smoke escaping into the atmosphere (as they now are in alkali works).* In some processes for making steel, hydrochloric, sulphurous, and nitrous acids are all given out, and cause eye diseases, bronchitis, pneumonia, and destruction of lung tissue.

Carbon disulphide was formerly used in the process of vulcanizing india-rubber, and produces headache, giddiness, pains in the limbs, muscular contractions, nervous depression, and insomnia; sometimes also deafness, dyspnœa, cough, febrile attacks, amaurosis and paraplegia (Delpech). The nervous system seems to be affected by it. This process is now being given up in favour of mixing the rubber with sulphur and vulcanizing by heat.

Paraffin vapour has been found to cause headache and loss of appetite in those exposed to it.

Effects of Air Impure from Several Substances always Co-existing.

Air rendered Impure by Respiration.—When the air is very impure, death ensues from the deficiency of oxygen and from the presence of poisonous *organic matter*, as in the notorious Black Hole of Calcutta; if, after inhaling it, immediate death does not ensue, then a febrile condition with boils and other evidences of impaired nutrition is produced, and may ultimately prove fatal.

When the air is not so impure, heaviness, headache, inertness, and nausea are produced; living continuously in a vitiated atmosphere—as in overcrowded houses or districts—produces anæmia, loss of appetite and strength, from the defective aeration and nutrition of the blood.

* *Vide* the Alkali, etc., Works Regulation Act of 1881 (it consolidates the Acts of 1863 and 1874); also the short Act of 1892 relative to hydrogen sulphide and other noxious vapours.

Such a condition very strongly predisposes to diseases of the respiratory organs, especially to phthisis, and assists in the more rapid spread of several specific diseases, especially typhus, plague, small-pox, scarlet fever, measles, and diphtheria. The severity of many diseases, especially the febrile, is increased, and convalescence prolonged.

Air rendered Impure by Combustion.—Theoretically, it may be that carbon and sulphur dioxide act as disinfectants to a certain extent, but practically infectious diseases are not less common in colliery districts or in smoky towns, while bronchitis is certainly due to the irritation of the respiratory passages. Statistics show an increase in the mortality from lung diseases during foggy weather.

The effects of breathing the products of combustion, especially of gas, are headache, heaviness, and oppression; breathed continuously, or for long periods, as in dark workshops, etc., anæmia and general want of tone are produced. Gas escaping in small quantities into bedrooms may produce a form of sore throat (Corfield).

Air rendered Impure by the Gas and Effluvia from Sewers and House-drains.—When sewers are well laid, well flushed, and not blocked, the men employed in them do not appear to suffer from any special liability to disease; but if the sewers be imperfect, after a time the air becomes extremely offensive; the breathing of this air (containing hydrogen and ammonium sulphides, carbon dioxide, nitrogen, and organic vapours) has produced vomiting and purging, headache, great prostration, and convulsive twitchings of the muscles, and even asphyxia. Where refuse of factories containing sulphuric acid finds access to the sewers the danger is much increased, and fatal results have been known to follow the sudden generation in them of sulphuretted hydrogen.

The continual escape of sewer air into houses, and especially into the bedrooms, causes an impaired state of health, especially in children, who lose appetite, become anæmic and languid; have diarrhœa, headaches, feverishness, sore throat, the fauces and tonsils being of a dull purple-red colour. Older persons suffer from headache, malaise, feverishness, and sore throat. It also aggravates the severity of all the exanthemata, and predisposes to other diseases.

The experiments of Alessi have demonstrated the important influence the inhalation of sewer air has in the production of enteric fever. He found that an almost innocuous growth of the micro-organism of this disease, after exposure to sewer air, was rendered highly virulent and extremely fatal to animals into which it was inoculated, and at the same time the vitality of animals inhaling this air was much diminished, so that there was greater inability to throw off the disease.

Growths of other organisms, usually harmless, were also found to prove fatal to animals so exposed.

Sewer Air.—Dr. Fischer of New York, in forty examinations of moist sewer air, detected in twelve instances pathogenic bacilli, of which some were Klebs-Loeffler's diphtheria microbe, and one was the *Bacillus typhosus*, and in sewer air which had passed into private and tenement houses where cases of diphtheria had occurred, he detected virulent organisms.

Owing to the varying height of sewage in sewers, a moist deposit, covered with a slimy fungous growth, is formed on their walls, and it has been contended that it is impossible for evaporation or even for powerful ascending currents of air to convey germs into the atmosphere from the surface of such deposits. Such conveyance, however, undoubtedly does occur, and Arthur suggests that it is effected by the bursting of ripe sporeheads of moulds, which grow on these deposits, and which, when they burst, carry the bacteria clinging to them into the air. It is probable that the entrance of hot water into sewers renders the conditions more favourable for the growth of microbes, and may even change benign bacteria into malignant; but these risks should be minimized if the sewers are well and truly laid, the pipes smooth inside and properly jointed; if they flush clean and are properly flushed as frequently as required. The opening of cesspools and of soil-polluted ground has been known to cause attacks of diarrhœa, and even enteric fever. Parry, Laws, and others think that some of the ill-effects which have been ascribed to sewer air may be due to subsoil air derived from soil polluted by constant infiltration of excremental matter through a leaky drain.

No harm seems to follow the application of fresh sewage

to the ground, but if decomposition has fully set in, the deodorizing and absorbing powers of the earth may be overtaxed, and disease might be caused; as also with improperly-managed sewage-farms.

Emanations from Streams polluted by Fæcal Matter.—Evidence as to disease from this cause is conflicting; the problem in any given case would be affected by the degree of dilution of the fæcal matter, and the presence or absence of currents or tides.

The air of streets which are not thoroughly cleansed must, during dry and windy weather, contain quantities of decomposing organic matter and pyogenic organisms, which, lodging in the eyes, nose, or tonsils, may set up irritation, and even give rise to septic poisoning, follicular tonsillitis, quinsy, etc.

Manure factories do not appear to affect the health of those engaged in them, if properly worked, and if the poudrette is not allowed to decompose.

The air of churchyards and vaults is richer in CO_2 and organic matter than ordinary air; and in vaults there are also hydrogen and ammonium sulphides, nitrogen, etc., so that cemeteries, thickly crowded with dead, have a lowering effect upon the health of the people living near, and increase the amount of sickness and mortality.

The effluvia from putrefying human bodies has been known to cause asphyxia, febrile attacks, gastric disturbances, pneumonia, pulmonary abscess, etc.

Air of Brickfields.—The kilns evolve carbon dioxide and monoxide, hydrogen sulphide, and sulphur dioxide, and a peculiar smell, which may be perceptible several hundred yards off. If only coal-dust be used, it may not be so offensive, but round London and towns remote from coalfields the contents of dust-bins and other refuse are used, with the evolution of offensive vapours, and there is also a sickening stench from the accumulation of such refuse, especially in warm weather after rain. The air, as it escapes from kilns, is rapidly fatal, but it is soon diluted and respirable. The smoke and gases from cement works destroy vegetation near.

Air from bone-burning, tallow-making, and other offensive trades, is full of very disagreeable animal vapours,

which are certainly a nuisance, if not always injurious to health.*

Air of Marshes.—Hydrogen sulphide is given off by marshes containing sulphates in the water; sulphides are formed by the action of organic matter, and SH_2 is liberated by the vegetable acids. Carbon dioxide, marsh gas, and organic matter are also present with various vegetable and animal matters. The *plasmodium malariæ*, which is now known to be the infective agent in malarial fevers, has been proved to be conveyed by mosquitoes, and especially by the *anopheles* variety (*vide* chapter on Contagia).

Ventilation.

The secret of efficient ventilation consists in the constant supply of fresh air in such quantity as to replace that vitiated or exhausted by heat and by the occupants of the rooms, at such a velocity as to be imperceptible as a draught.

The **quantity of air required** to dilute or remove the respiratory impurities caused by healthy persons should be sufficient to remove all sensible impurity.

The maximum amount of respiratory impurity admissible in a properly-ventilated air-space, as measured by the carbonic dioxide, is 0·2 per 1,000, and as 0·4 already exists, the total amount permissible should not exceed 0·6 of CO_2 per 1,000. As 0·6 of a cubic foot of CO_2 per head per hour is exhaled, in order that the total impurity do not exceed 0·6 per 1,000, it is necessary that fresh air be admitted at the rate of 3,000 cubic feet per head per hour to a mixed community in good health and in repose.

For adult males...	3,600 cub. ft.	(1 cub. ft.	per	second).
„ „ females	3,000	„	„	„
„ children ...	2,000	„	„	„

Adults at work evolve more CO_2, and should have—

In light work...	4,750 cub. ft.	of fresh	air per	man.
„ hard „ ...	9,800	„	„	„

Large cattle, as horses and cows, ought to have from 10,000 to 20,000 cubic feet per hour.

* *Vide* Public Health Act, 1875, the Model By-laws, and Dr. Ballard's report on 'Effluvium Nuisances.'

Amount Required for the Sick.—The smell of organic matter is felt among the sick when the CO_2 has reached a much smaller amount than in the case of the healthy. The maximum amount of fresh air should be increased by *one-fourth*. In typhus, small-pox, and plague too much fresh air cannot be given.

Humidity bears a certain proportion to the other respiratory impurities, and fresh air is required not only for the removal or dilution of organic and inorganic impurities, but for the removal of excessive moisture. Watery vapour is given off into the air not only by respiration but also largely by artificial lights. It has been calculated that an increase of 1 per cent. of humidity has as much effect on the condition of an air-space, when judged by the sense of smell, as a rise of 4° to 18° F. (2° to 32° C.), organic exhalations being far more obnoxious to the senses in a moist than in a dry atmosphere. From 73 to 75 per cent. of humidity is the standard of moisture generally accepted in this country as consistent with comfort. If this humidity in a dwelling room is largely in excess of that of the outside atmosphere, a proportional amount of fresh air is required to absorb it, in addition to what is required for the removal of organic impurities.

Quantity of Air Required for Lights, etc.—A gas-burner consuming 3 feet per hour requires 5,000 cubic feet of fresh air. Nearly as much air must be given for 1 lb. of oil as for 10 feet of gas.

Cubic Space.—The minimum amount of cubic space allowable is calculated from the rate at which air can be taken through a room without the movement being perceptible or injurious.

The ideal initial air-space should be from 1,000 to 1,200 cubic feet for each person.

It is better to have a large than a small cubic space, because if anything interferes with the ventilation the ratio of impurity from respiration increases much faster in a small than in a large room.

It is a grave mistake to suppose that increased cubic space does away with the necessity of introducing fresh air or of changing the air in the space ; after a very short time—whether the air-space be small or large—the same amount of fresh air (3,000 feet) must be supplied every

hour, and in this climate it is not found possible to change the air of a room oftener than three times an hour; the air-space, therefore, should contain one-third the amount of air supplied per hour. With good warming and equable movement there would be a better distribution of the air, and the initial space might then be smaller.

The warmth of moving air influences the sensation of persons exposed to it thus:

At 55° or 60° F., a rate of 1½ feet per second (1 mile per hour) is imperceptible.

" " 2 to 2½ feet per second (1·4 to 1·7 miles) is imperceptible to many, and this is a good speed for air to enter rooms.

" " 3 feet per second (2 miles) is perceptible to most.

" " 3½ feet per second is perceptible to all.

Any higher rate would be felt as a draught, especially if the entering air be of a different temperature or moist.

At 70° F. a rather greater velocity is not noticed, but above 80° F. or below 40° F. the movement is rather more perceptible.

Soldiers are only allowed 600 cubic feet per man, and phthisis is unduly prevalent in barracks in consequence.

Three hundred cubic feet is the quantity specified in the Model By-laws for common lodging-houses, and two children under ten count as one adult.

The same amount is prescribed for sleeping rooms in houses let in lodgings or occupied by members of more than one family, 400 cubic feet being required if the room is also used as a living room. These amounts should be regarded as minimal, and as falling far short of ideal requirements. No reduction should be allowed in the case of children. Two hundred and fifty cubic feet has been taken as the standard for factories and workshops, 400 cubic feet being required during overtime; but local authorities have power to exact a higher standard for workshops other than factories.

The mortality from phthisis in common lodging-houses is appalling. Due allowance must be made for the fact

that these places are largely the resort of the 'submerged tenth,' casual labourers and others, whose tendency to phthisis is partly the cause, partly the result, of their general unfitness for the battle of life; but it can hardly be denied that the inadequate air-space of common lodging-houses contributes largely to this mortality.

In new schools the Education Department require a minimum of 100 cubic feet, and 10 square feet of floor-space for each child. For existing schools and for infants 80 cubic feet and 8 square feet are prescribed.

In ordinary hospitals the cubic space should be 1,500 to 2,500 feet, with at least 72 square feet per bed (H. Acland); 100 or 120 square feet would be better. A minimum floor-space must be insisted upon in all cases, and it should not be less than one-twelfth of the cubic space. In fever hospitals 2,000 cubic feet, with a floor-space of 156 square feet, should be aimed at for each bed. Where diphtheria cases are under treatment 2,500 cubic feet should be provided.

For horses, 1,200 to 1,800 cubic feet, with 100 to 120 square feet of floor, should be given; roughly, 2 cubic feet of space for every pound avoirdupois the animal weighs, the floor-space being not less than one-twelfth of the cubic capacity. Dr. Ballard recommended that cattle should have at least 1,000 cubic feet allowed per animal, but the Local Government Board have suggested 800 cubic feet for each cow as a suitable minimum air-space in cowsheds.

Ventilation may be effected in two ways:

1. By taking advantage of natural forces, variations of barometer pressure, and of temperature, diffusion, winds, etc.

2. By the use of mechanism, steam-jets, fans, water power, blowing engines, hot air, etc.

Diffusion.—Every gas diffuses inversely as the square root of its density. Diffusion goes on through the pores of various solids, such as brick or stone, but plastering and papering reduce diffusion through the walls of houses to a minimum; it goes on, however, through chinks and openings produced by imperfect carpentry, but not to an extent sufficient to keep the air pure; moreover, although the carbonic oxide may be got rid of to some extent, the

organic matter, which does not obey the above law, and which exists in clouds in a room, is not appreciably affected.

The Action of Winds: (1) *By Perflation.*—If the wind can pass freely through a house or a room the air will be changed a great many times, but the direct action of the wind is diminished when a through current cannot be obtained, as in houses built back to back, in alleys and narrow streets, or when windows and doors are not suitably placed, or obstructions in the shape of furniture, etc., exist.

The wind will pass through walls of wood (single-cased), and through bricks and stone, especially when there is a difference in temperature and moisture; plaster and mortar act as obstructions.

The great objection to ventilation by wind in this way is the uncertainty of movement and difficulty of regulation.

(2) *By Aspiration.*—A small current of air at a high velocity can set in motion a large body of air by driving the air before it. A partial vacuum is produced, towards which all the air in the vicinity flows at about right angles: thus the wind blowing over chimneys or other tubes draws up the air; it may, however, obstruct the exit of air by blowing against the opening; this may be prevented by the use of a cowl.

The ventilation of ships is carried out by utilizing wind by means of cowls, tubes, fans, wind-sails, etc.

(3) *By the Difference in the Weights of Masses of Air of Unequal Temperature.*—This is, of course, the cause of wind, and by it rooms, which are hotter than the external air, may be efficiently ventilated; it is, therefore, more active in winter than in summer. A fall of pressure of 1 inch causes the abstraction of 57 cubic inches of air from every cubic foot of the nearly closed space, and a rise of internal temperature of 1° F. causes the expulsion of $3\frac{1}{2}$ cubic inches. Changes of air are thus effected in wells, cupboards, cases, cellars, cesspools, and other places, even when they have no apparent openings. And similar causes produce an expulsion of air from all soils which are porous and contain a quantity of air dependent on the barometric pressure.

Various Methods.—In all the numerous methods employed to effect ventilation certain points must be observed. The air supplied should not be derived from an impure source nor drawn through dirty tubes or basements. All delivering shafts should be short, readily accessible, and easily cleaned. If the air is dirty, it should be filtered. Coarse jute cloth (light Hessian) makes a good filter, which can be easily and cheaply replaced (Carnelley); it may be employed dry, or kept moist by a stream of water falling on it; or the air may be drawn through cotton-wool (House of Commons) or made to impinge upon a tray containing water or some disinfectant fluid, in which dust, soot, etc., will be deposited.

The air should be *warmed* or *cooled*, according to the season or locality, before entering the room. The *distribution* of the fresh air should be uniform; this can be ascertained by calculating from the observed CO_2 the amount of air used in a given time, and comparing it with the actual movements of the air as measured with an air-meter; the two quantities should not differ materially.

The *outlet* for vapours or gases should be in the upper part of a room; for heavy powders, in the lower part.

Friction interferes largely with proper ventilation, and must be calculated for in any system. The causes of friction are:

The *length* of the tube or shaft—the longer the tube the greater the friction. The *size* of opening—for similar sections the friction is inversely as the diameter; or, if the shapes be not similar, the ratio is as that of the square roots of the respective areas (Morin). Thus, if an opening be divided into so many smaller ones there is great loss from the friction set up.

Shape of Opening.—A circular opening includes the greatest possible area within the smallest periphery. The loss by friction from use of any other shape will be in the proportion of the lengths of the peripheries.

Angles are the most serious cause of loss in velocity of currents in tubes—every right angle diminishes the current one-half; angles should be avoided as much as possible, but when they must be employed should be rounded off. (This factor is constantly ignored by house-

builders in the ventilation shafts of soil-pipes and drains It is very common to see these shafts taken round two or more right angles to avoid the eaves and rain-gutters of houses, instead of being led straight up. Shafts thus constructed are almost useless for purposes of ventilation.) The presence of dirt, soot, etc., also causes friction.

The openings of shafts should be circular or elliptical, as there is less loss by friction and less chance of lodgment of dust, etc., and they can be more easily and thoroughly cleaned.

To obtain perflation by the wind to the best advantage, windows should be placed on opposite sides of the room. Various simple contrivances may be adopted to direct the currents of air, as oblique holes in the glass, double panes, louvres, raising lower sash and placing a piece of wood below it so that air enters at the space between the sashes (Hinckes Bird), or holes may be cut at the junction of the upper and lower sashes; double ceilings, the lower perforated and the space between open to the air, have been suggested for workshops and factories (Stallard).

Special openings may be provided; a cowl has no advantage over an open tube, which may be provided with a conical cap and a flange for an up-draught, or with trumpet-mouth and inverted conical cap for a down current. Ellison's conical bricks have cone-shaped holes pierced in them, the smaller end of the cone being outermost; the entering air is distributed so that no draught is felt, even close to the openings. In the above-named contrivances the movement caused by the difference of weight of unequally heated bodies of air also acts; but, as the external temperature in this country necessitates closing of windows and doors, it is desirable to have special openings by which ventilation may be regulated. It is necessary to provide inlet, entrance, or adduction openings as well as outlet, exit, or abduction ones.

Size of all Openings.—This is difficult to fix exactly, as it depends not only upon the height of the column of air, but also on the temperature, which is a variable quantity. Tables have been constructed from Montgolfier's formula,* showing the velocity of the air with

* The velocity in feet per second of a falling body=eight times the square root of the height through which it has fallen.

varying height and temperature by finding the difference in the pressure of the air inside and outside the room. Dr. de Chaumont suggested this formula for the same purpose :

$$V = 8\sqrt{\frac{(h-h')(t-t')}{491}} = \text{velocity in feet per second.}$$

When h = height of aperture of exit from ground.
h' = height of aperture of entrance from ground.
t = temperature of the inside air in degrees Fahrenheit.
t' = temperature of the external air in degrees Fahrenheit.
$\frac{1}{491}$ = the ratio of expansion of air for each degree Fahrenheit.

An allowance of one-quarter to one-half is usually made for loss by friction. To ascertain the amount of air entering a room in a given time, multiply the ascertained velocity by the area of the inlet.

The average size per head for the inlet opening should be 24 square inches, and the same for the outlet. In a small room this could not be borne unless the air were warmed in cold weather. It is better to have several small inlet openings than one large one, distribution being better carried out. Thus each inlet opening should be of sufficient area for not more than two or three persons, and each outlet not more than 1 square foot, or enough for six persons. Inlet tubes should not be placed too near an outlet ; if placed at the bottom of a room, the air must be warmed ; if placed higher, the tube should end in a trumpet-shaped form, and so turned that the air may be directed upwards. The air may be warmed by (*a*) passing through boxes containing hot-water or steam pipes ; (*b*) or by passing it into air chambers behind or round grates and stoves ; (*c*) or in a tube passing through a stove. 'Tobin's tubes' are well known for the introduction of air from the outside.

Outlets.—For small rooms the chimney is the best outlet that can be had. An ordinary fire will pass through it from 3 to 6 cubic feet of air per second. When other outlets have to be provided they should be placed at the

highest part of the room, the tubes protected as much as possible between walls and with a cap to prevent entrance of wind and rain, else the air in the outlet tube will become cooled so that it cannot overcome the weight of the superincumbent atmosphere. All outlets should be placed at the same level in a room. When heat can be employed, the discharge of air is rendered more certain and constant; hence advantage should be taken of the heat from the open fire by making an opening, with a talc valve, into the chimney at the highest part of the room, or by surrounding the flue with extra tubes leading the foul air from the other parts of the room if it be a large one. The heat from gas-burners may also be utilized by having an outlet-pipe over the burner. The consumption of 1 cubic foot of gas will cause the discharge of 1,000 cubic feet of air.

McKinnell's ventilator, consisting of two open tubes, one inside the other, the inner tube terminating in a conical expansion, is sometimes useful when it can be carried readily to the open air from the ceiling; for instance, in halls, schoolrooms, or churches. The fresh air descends by the outer tube; the foul air ascends by the inner one.

Galton's ventilating fireplace is a good device for ventilating as well as warming rooms (*vide* Warming of Houses).

Artificial Ventilation.—This is effected in one of two ways—viz., by extraction (*vacuum* method) or by propulsion (*plenum* method).

Extraction, by which the air is drawn out of a building, may be by use of heat, the steam-jet, or by a fan or screw. With an ordinary sitting-room open fire there is a constant current up the chimney even in summer. Without a fire there is often an up-draught. It may be taken as an average that the chimney affords an outlet sufficient for four or five persons. A down current, sending puffs of smoke into the room, shows that there is an insufficient supply of fresh air, and an inlet should be provided. Extraction of the air of a whole building may be performed by a central shaft having a fire at its base, or hot-water or steam-pipes may be used instead. In theatres the heat from the chandeliers, sunlight burners, etc., may be utilized for the same purpose.

Objections: Inequality of draught due to atmospheric influences and to changes in the quantity and quality of the combustibles.

Inequality of the movement from different rooms.

Possibility of the reflux of smoke and of air.

Impossibility of controlling the places where fresh air enters.

A steam-jet can be employed in factories. It is allowed to pass into the chimney. Tubes passing from the different rooms enter the chimney below the steam-jet, which will set in motion a body of air equal to 217 times its own bulk. An extracting fan may be used for the same purpose.

This method is suitable for either small or large buildings, for coal-pits, mills, etc. The fan may be worked by steam, electricity, or other motor power.

Propulsion (Plenum) Methods of Ventilation.—Fresh air is driven into a room at a low level, so as to force out the air already in the room at or near the ceiling. This is usually done by means of fans (as the Blackman air-propeller). The amount of air delivered can be told by ascertaining the speed of the extremities of the fan per second; the effective velocity is three-fourths of this. Multiply by the section area of the conduit, and the discharge can be ascertained. This is the most perfect method of ventilation, as the air is under complete control in every way, and may be screened, purified, warmed or cooled, dried or moistened, as required.

The punkah is an air-propeller, but not so perfect in action. A modification of it, introducing chemical purifiers, has been recommended for tunnels, hospitals, rooms, etc.

Unless motor power can be obtained readily from an engine *in situ* the cost of this method may be large: there are chances of the engine breaking down; attention is required for details; and there is some difficulty in distribution. The use of a water-spray to set the air in motion, as in Verity's system, or of a water-motor, may be found useful, and easier to work than steam power.

The Relative Value of Natural and Artificial Ventilation.—The special conditions of each case must determine the choice of method best suited.

Natural ventilation is cheaper than any form of artificial, but for large buildings it is less effective. Mechanical methods can be more readily controlled, and the air may be cleansed. cooled or warmed, dried or moistened, as required.

In the tropics, with warm stagnant air, and in temperate climates, in buildings with numerous small rooms, or where sudden assemblages of people take place, mechanical ventilation is indicated. For schools Professor Carnelley found that better results were obtained from mechanical ventilation. He states that the air is better distributed, CO_2 is less, micro-organisms are fewer, the temperature is more equable, draughts are prevented, and that a higher Government grant is obtained by the children in schools mechanically ventilated than in those depending upon natural ventilation only.

To Determine the Sufficiency of Ventilation.

The cubic space and floor-space per person and the relation to each other, the number of cubic feet of fresh air which each person receives per hour and the completeness of its circulation throughout the room, must be determined, and the quality of the air must be examined by the senses, and by chemical and biological methods.

1. **Cubic Space.**—This is ascertained by multiplying the length, breadth, and height of a room into one another if the room be a square or oblong one with a flat ceiling. If of irregular shape, then according to the following formulæ:

Circles.—To determine areas, circumferences, etc., use is made of the fact that the circumference is 3·1416, or, roughly, $3\frac{1}{7}$ times the diameter, thus:

Area of circle	$= D^2 \times 0{\cdot}7854.$
" "	$= C^2 \times 0{\cdot}0796.$
Diameter of circle	$= C \div 3{\cdot}1416.$
Area of a square	$=$ length $\times$ breadth.
Area of rectangle	$=$ length $\times$ breadth.
Area of triangle	$= \begin{cases} \text{Base} \times \frac{1}{2} \text{ height, or} \\ \text{height} \times \frac{1}{2} \text{ base.} \end{cases}$

Area of any figure bounded by right lines	=	Divide into triangles and take the sum of their areas.
Cubic capacity of a cube or solid rectangle	=	Multiply together the length, breadth, and height.
Cubic capacity of a cone or pyramid	=	Area of base × $\frac{1}{3}$ height.
Cubic capacity of a dome	=	Area of base × height × $\frac{2}{3}$.
Cubic capacity of a cylinder	=	Area of base × height.
Cubic capacity of a bell-tent	=	That of a cone resting on a short cylinder.

The cubic capacity of a hospital marquee, a building with a dome, or such-like, may be found by dividing the room into several parts and measuring them separately.

Any recess containing air should be measured, and the amount added. Deductions calculated from actual measurement have to be made for solid projections, large pieces of furniture, bedding (a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets occupy about 10 cubic feet), and for the bodies of persons living in the room (the weight of a man in stones divided by 4 gives the cubic feet he occupies) — roughly, 3 cubic feet per head will cover all deductions. It will be found convenient and a saving of time at examinations to use decimals of a foot instead of inches. Square inches may be turned into square feet by multiplying by 0·007. It is not usual to take into consideration any space higher than 14 feet from the floor, as the organic matter does not rise above this height as a rule. The total number of cubic feet, after all additions and deductions have been made, is then to be divided by the number of persons living in the room ; the result is the cubic space per head. Total area of floor-space divided by number of persons gives the floor-space per head, which should be one-twelfth of the cubic space.

2. **Movement of Air in a Room.**—Note the various openings, the distance between them, how they open, and on what external place they open ; ascertain in what way

the air moves in the room by means of smoke from smouldering cotton-velvet, noting the apparent rapidity; measure the various openings—the chimney should be measured at its throat, or narrowest part. It is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter; but the amount of movement in both inlets and outlets may be measured by an *anemometer*, or air-meter, which should be placed well into any shafts or tubes at a point about two-fifths from the sides of the tube, so that the little sails may be made to catch the centre of the current of air. The mean velocity will then be registered on the dial. If this linear discharge be multiplied by the sectional area of the opening, the cubic discharge is obtained. This should then be calculated per hour and divided by the number of persons in the room, which will yield the discharge per head for that particular opening. A *manometer*, or pressure gauge, should be used instead of the anemometer for chimneys or other places where there is either dust or heat. The velocity of the current is calculated from the height to which it drives a column of water. In recording the velocity of air at openings, it is usual to denote an incoming current by a plus sign, and an outgoing by a minus. If the ventilation of a room is influenced by the wind, the horizontal movement of the external air should be determined by an air-meter.

When the final analyses are made, the amount of air supplied and utilized should be compared with the amount of movement as shown by the air-meter. If the distribution is good they will agree fairly. If they differ, an excess by the air-meter means bad distribution; a deficiency indicates that some inlet has been overlooked. If the external air is tranquil and the air in the room is uninfluenced by it, the amount of discharge may be calculated approximately by the law of Montgolfier.

Examination of the Air of Rooms, Sewers, etc.

1. **By the Senses.**—The degree of smell of animal organic matter in a room may be taken as an approximate measure of the CO_2. The humidity of the air has a very marked influence in rendering it more perceptible. The effect of an increase of 1 per cent. in humidity is as great

as a rise of 4·18° F. in temperature; but on the average the smell of organic matter is perceptible when the CO_2 reaches over 0·6 per 1,000 volumes, and is very strong when the CO_2 amounts to 1 per 1,000.

2. **Microscopical Examination.**—The existence and character of suspended matters is judged of by immediate observation under the microscope, and after cultivation in prepared nutrient media.

Pouchet's aëroscope may be used to collect the suspended matters, which are collected on a drop of glycerine, or air may be drawn through distilled water, or through glass threads dry or wet with glycerine, or through a layer of powdered sugar.

A good way is to take a small bent tube, wash and dry it, and heat it to redness. When cool place in a freezing mixture, fix a sterilized indiarubber tube at one end, and then air may be slowly drawn through. The water of the air will condense in the tube and carry most of the solid particles with it. A drop may then be taken on a glass rod, previously sterilized by heat, and examined at once on a clean glass with an immersion lens.

Or Hesse's method may be employed: The air is drawn through a tube containing nutrient gelatine, which has been previously sterilized; on this moulds, fungi, and other micro-organisms grow, and can be examined. It will be found that moulds and fungi preponderate in pure air, whilst in air rendered impure by the presence of organic matter derived from respiration, etc., microbes are in excess.

The quantity of air drawn through should be measured. A vessel holding a known quantity of water is employed, connected on one side with the gelatine or other filter-tube, which is open on the other side to the air to be examined. As the water is run off air is necessarily drawn in through the filtering medium. At 39° F., the maximum density point of water, an imperial pint contains 34·659 cubic inches—1,000 fluid ounces = a cubic foot.

De Chaumont considered that the best plan was to carry the air through a succession of bottles containing pure distilled water; the sediment could then be examined microsopically, and the liquid part chemically.

The results of Dr. Miguel's bacteriological examinations of the air in Paris and on the Alps have already been referred to (*vide* p. 89).

3. **Chemical Examination**—*Carbon Dioxide* (Pettenkofer's method).—A bottle capable of holding a gallon ($4\frac{1}{2}$ litres) is filled with water in the place the air of which is to be examined, and slowly allowed to drain out; then 60 c.c. of clear lime or baryta water are put in, and the mouth closed with an indiarubber cap. After thoroughly shaking up the solution, the bottle is allowed to stand for an hour if baryta water has been used, for six or eight hours if with lime-water. CO_2 is absorbed and the causticity of the fluids is reduced. The difference between the first and second degrees of causticity represents the CO_2. Titration against a standard solution of oxalic acid is employed to determine this; a solution of phenol-phthallein, or methyl-orange, being used as an 'indicator' to ascertain the exact moment of neutralization. Deduct 60 c.c. from the total capacity of the bottle (to account for the space occupied by the lime-water), and state the capacity in litres and decimals. Divide the c.c. of CO_2 by the corrected capacity of the bottle; the quotient is the c.c. of CO_2 per 1,000 volumes of air.

Correction must be made for temperature. Add 0·2 per cent. to the result for each degree above 32° F., and subtract for each degree under.

Correction for pressure is unnecessary, unless the place is much removed from sea-level, as $\frac{1}{10}$ inch of pressure causes a difference of only 0·26 per cent. To correct for pressure, use this formula:

$$\left.\begin{array}{c}\text{As standard height}\\ \text{of barometer}\\ \text{29·92 inches or 760 mm.}\end{array}\right\} : \left.\begin{array}{c}\text{Observed height}\\ \text{of barometer}\end{array}\right\} :: a : x$$

$a = CO_2$ corrected for temperature
$x =$ " " " " and pressure.

In Lunge and Zeckendorff's method a standard solution of carbonate of soda and phenol-phthallein is employed. Air is driven by compression of an indiarubber ball holding 70 c.c. into a bottle which contains 10 c.c. of this solution, and the bottle well shaken after each com-

pression till the red colour has been discharged from the solution. From the number of times it has been necessary to compress the ball the proportion of CO_2 in the air is estimated by reference to a table. By this method the CO_2 may be quickly determined with a fair degree of accuracy, and the apparatus is readily portable.

Carbon monoxide (*carbonic oxide*) may be detected by its absorption from a measured quantity of air by a solution of cuprous chloride in a Hempel apparatus. A method which is at once simple and more delicate is Vögel's spectroscopic test. A small animal may be introduced into the suspected atmosphere and its blood examined, or a little blood from a human finger may be dropped into a jar containing the suspected air to which a small quantity of distilled water has been added. The jar and its contents must be well shaken up and some of the liquid examined with the spectroscope. The spectrum of carbonic oxide hæmoglobin resembles that of oxyhæmoglobin in exhibiting two well-marked bands in the yellow and green parts of the solar spectrum between Fraunhofer's lines D and E, but the left-hand band (yellow end) of the carbonic oxide hæmoglobin lies a little nearer to the right (blue end) than in the case of oxyhæmoglobin. If two drops of a colourless solution of ammonium sulphide be added to the liquid and no marked change occurs in the spectrum after shaking, carbonic oxide is *present*, otherwise, the ammonium sulphide having deoxidized or reduced the hæmoglobin, the two bands will be represented by a single band shaded off at its borders, and occupying a position intermediate with regard to the two original bands. This test is sufficiently delicate to detect as little as 0·03 per cent. of carbonic oxide.

Carbonic oxide, if present in considerable quantities, produces a characteristic cherry-red colour in the blood of an animal. It forms a stable combination with hæmoglobin, and is not displaced by addition of oxygen, as by artificial respiration. Welzel has devised a delicate chemical test for carbonic oxide hæmoglobin. To 10 c.c. of the solution of blood he adds 5 c.c. of a 20 per cent. solution of potassium ferrocyanide and 1 c.c. acetic acid (1 vol. of glacial acetic acid to 2 vols. of water); the

precipitate very soon becomes reddish-brown if carbonic oxide hæmoglobin be present, but grayish-brown with oxy-hæmoglobin, the difference slowly disappearing (Kenwood).

Ammonia.—The estimation of free ammonia and of nitrogenous matter in air by conversion into albuminoid ammonia is performed by Wanklyn's method, as described under Water Analysis.

The quantity of air drawn through the aspirator must be accurately estimated. The results are calculated in milligrammes per cubic metre (1 cubic metre = 1,000 litres = 1,000,000 c.c.

The presence of ammonia in the air can be ascertained by exposing strips of filtering paper, dipped in Nessler's solution.

Estimation of the Oxidizable Matters in the Air in terms of Oxygen.—Potassium permanganate is used for this purpose; it acts upon the putrescible organic matters, hydrogen sulphide, nitrous acids, tarry matters, etc.

Nitrous or nitric acids are determined, in the same way as in drinking-water, from the washings of the air.

Watery vapour is ascertained by the dry and wet bulb thermometer, by Dines' direct, or by Saussure's, or Wolpert's horse-hair hygrometer.

The examination of the air of a room should be repeated at intervals, and simultaneous observations should be made of the air outside. There should be only sufficient lights for working purposes, and no smoking allowed.

At examinations for public health diplomas it is usual to present two or more large clear glass-stoppered bottles to each candidate, in order that he may ascertain qualitatively what gases they contain. The steps taken in the process should be stated.

The bottles are likely to contain one or more of the following:

Carbon dioxide.
Hydrogen sulphide.
Hydrochloric acid.
Nitrous acid.
Sulphurous acid.
Chlorine.
Bromine.
Ammonia.
Ammonium sulphide.
Carbon disulphide.
Coal-gas.
Common air.

Directions for Testing.—1. Note colour—Chlorine, greenish yellow; nitrous fumes, brown red.

2. Note smell—Raise the stopper slightly for as short a time as possible, as the gas may escape if present in small quantity; there is usually sufficient to enable the observer to distinguish what is present.

3. Note any fumes which escape—Red fumes of nitrous acid.

4. Use test-papers—Red litmus, blue litmus, turmeric, lead acetate, starch and potassium iodide, potassium bichromate. Moisten them with water, and fix them between the stopper and neck of the bottle.

Acids turn blue litmus paper red.

Ammonia turns red litmus paper blue and turmeric paper brown; papers wet with Nessler's reagent may be used.

Chlorine bleaches paper with vegetable colouring.

Hydrogen and ammonium sulphide turn lead acetate paper black, the latter showing also an alkaline reaction.

Nitrous acid turns starch and potassium iodide paper blue; so also do ozone, peroxide of hydrogen, and chlorine; but the latter do not possess the red fumes, nor do they show an acid reaction.

Ozone is not soluble in water; hydrogen peroxide is, and gives a blue colour on addition of chromic acid. Ozone possesses a characteristic odour: a bichromate paper is turned from yellow to green if much sulphurous acid be present.

5. Introduce a glass rod which has been dipped in ammonia; if hydrochloric acid be present white fumes of ammonium chloride will be formed.

6. Ignition—Carbon disulphide and coal-gas, when mixed with air, combine with violence on ignition. Coal-gas leaves CO_2 only, carbon disulphide CO_2 and SO_2.

7. If the contents of the bottle have a smell, and any doubt remains as to the gas or gases, add gently a little water, shake thoroughly, and test the solution with appropriate reagents—*i.e.*, ammonia compounds with Nessler's solution; sulphurous acid with bromine water; nitric acid with bromine water; nitric acid with chloride of barium solution (white precipitate), etc.

8. If the contents of the bottle are odourless, common

air or carbon dioxide, or both, are present. Instead of adding plain water add a little lime-water ; shake well. If the fluid becomes milky it shows the presence of CO_2. If there be any doubt as to whether more CO_2 is present than is in ordinary air, add some lime-water to a clean bottle containing ordinary air ; shake well and compare.

CHAPTER V.

SITES, BUILDINGS, ETC.

To insure healthy habitations five conditions must be observed. These are :

1. A dry site, and an aspect which gives light and cheerfulness.

2. A pure supply and proper removal of water.

3. A system of immediate and perfect sewage removal.

4. A sufficiency of open space to insure thorough ventilation in and around the building.

5. A condition of house-construction which shall insure perfect dryness of the foundations, walls, and roof, and freedom from entrance of ground-air.

As to **site**, the points to be considered are :

(*a*) The geological formation.
(*b*) The aspect with regard to heat and light.

(*a*) **Geological Formation.**—Granite, metamorphic, and trap rocks, clay, slate, and the hard millstone grit formations, yield good sites. They have good slopes, are impermeable, so that water runs off readily, vegetation is not excessive, no impurities are added to air or water. Water is sometimes scarce. Of limestone rocks, hard oolite (made up of small rounded grains) is the best, and magnesian the worst. They resemble those already mentioned, except that there is more tendency to marsh formation, and drinking-water is plentiful and sparkling, but hard. Pure chalk forms a healthy site, being permeable, but care must be taken that wells are not contaminated. If chalk be marly (mixed with lime and clay) it becomes impermeable and damp. Sandstones, when permeable.

are healthy, but the same precautions must be taken as with chalk. Gravels of any depth are healthy unless much below the general surface; permeable soils, if low-lying, are all apt to become contaminated with organic animal matter, and give rise to diarrhœal diseases. Gravel hillocks are the healthiest of all sites, but the building should be placed at the summit rather than on the side or near the foot of a hill, as these two latter sites are apt to be damp. Sands, when pure, are healthy, but are not so if mixed with iron and vegetable sediment (as in the Landes in South-West France), or from underlying clay near the surface, or from being mixed with magnesium, lime, and soda salts. In cold countries sands are dry and warm, but in hot countries they are too hot, unless covered with herbage. Clay, dense marls, and alluvial soils are the most unhealthy; they are impermeable, and water does not run off them; they are, therefore, wet and often marshy; in temperate climates they form cold, damp soils, which favour rheumatism, catarrhs, and neuralgia; such soils may be much improved by drainage. Cultivated soils are often healthy, but not so irrigated lands, which give a great surface for evaporation and send up organic matter into the air. 'Made soils' are usually very impure, and building upon them should only be allowed after a lapse of time sufficient to allow all impurities to have disappeared; this will depend on the composition of the refuse, and the ease with which air and water obtain access to it; under the best circumstances, this may require three or four years. 'Made soil' may consist of any waste material, from the rubbish of a builders' yard to animal and vegetable filth of all kinds. Summer diarrhœa is generally apt to be prevalent where habitations are built on made soil. Clinker is the least objectionable material for filling up building sites.

Ground-Air.—All soils except the hardest rocks contain air, the loosest sands as much as 40 or 50 per cent. In towns it consists of CO_2, ammonia, nitric acid, and sometimes carburetted hydrogen and hydrogen sulphide, coal-gas from faulty pipes, air from cesspools and broken or porous drains. This air is in continual movement, especially when the soils are dry. This is caused by the changes of heat in the ground, rainfall, barometric pres-

sure, and alterations in the level of ground-water. The warmth of the air in houses will draw this impure ground-air up into the house unless the basements be covered with concrete or some impervious material. Sir Charles Cameron explains the incidence of enteric fever in Dublin upon dwellers on gravel rather than on those living on the clay by the facility with which ground-air may be forced up into houses and unpaved streets from the former stratum.

Samples of air contained in soils may be obtained by driving into the ground at various depths a sharp-pointed, perforated steel tube, through which the air may be aspirated into a glass jar.

Ground or subsoil water is that condition in which all the interstices of the soil are filled with water, so that, except in so far as its particles are separated by solid portions of soil, there is a continuity of water (Pettenkofer). When air as well as water is present the ground is merely moist. Even the hardest rocks absorb some water, but they are usually regarded as impermeable; while chalk, sand, sandstone, vegetable soils, etc., are called permeable. Humus may hold as much as 40 to 60 per cent. The subsoil water exists at various depths from 2 feet to 300 feet. The level frequently changes, due to rainfall, pressure of water from rivers or the sea, alterations in outfall. A uniformly low ground-water is the most healthy, but uniformly high ground-water is preferable to one that fluctuates, especially if the fluctuations be rapid and considerable. A high ground-water causes a cold soil and a misty air, and its varying level aids the evolution of organic emanations from the impurities in the soil. One grain of water in evaporating carries off sufficient heat to raise 960 grains of water through 1° F.

The diseases which are influenced by the condition of the ground-water are: Rheumatism, neuralgia, catarrhs, paroxysmal fevers, wasting diseases of the lungs, and probably also diphtheria, malaria, cholera, enteritis, and enteric fever. The height of the ground-water may be measured by the height at which water stands in wells (local conditions which might affect wells being known). To render the soil drier, deep drainage and opening the outflow are resorted to.

Dr. Adams believes that increased movement of the ground-water, when contrasted with the more stagnant condition, is salutary, probably because it is a means of washing and aerating the soil, purging and purifying it from disease organisms. Dr. Newsholme has shown that a year in which the ground-water is at a low level, accompanied by a high temperature, is likely to be characterized by an epidemic of rheumatic fever. The association of this disease with opposite conditions may perhaps be explained on the hypothesis that a light rainfall in any locality, combined with a heavy fall in other parts of the same river basin, may, by raising the level of the ground-water, drive out air laden with the specific contagium, or wash it into the wells, whereas a heavy rainfall in the district washes away the contagium. The contagium of malaria is distinctly influenced by the level of the ground-water.

(*b*) **Aspect as to Heat and Light.**—Isolated houses and hospitals should be placed so that they are protected from the prevailing winds, and have as much exposure to the sun as possible. Vegetation prevents the sun's rays from reaching the ground. The removal of woods renders the climate more equable and drier, but may, if carried too far, lower the rainfall to an injurious extent. In hot countries the evaporation from the vegetation is so great as to lower the temperature. Vegetation also obstructs the movement of the air, which may be harmful or the reverse according to position. A belt of forest is generally considered to be a barrier to the transmission of malaria. (Eucalyptus trees are especially serviceable in this respect.)

In towns houses should be arranged so as to have a due circulation of air, back as well as front, and a due proportion of sunlight. The height of buildings should be so regulated that they do not shut out the sunlight from neighbouring houses (see 'Model By-Laws' and London Street and Buildings Act, 1894).

On this point the Local Government Board report on 'Back-to-back Houses,' by Dr. Barry and Mr. Gordon Smith, may be read with profit. It shows that the practice of building such houses without provision for through ventilation is still in vogue in Yorkshire towns ; that the

system tends to overcrowding, the storing of excreta in the house till dusk, and other evils; and that mortality from all causes, as well as from diarrhœa, pulmonary diseases, phthisis, and the chief zymotic diseases, increased *pari passu* with the proportion of back-to-back houses in the district.

In crowded streets and narrow courts the proportion of carbonic acid in the air, which is the measure of organic impurity, is demonstrably in excess; and in houses situated in these localities even free opening of windows does not purify the air, but only admits air slightly less vitiated than that of the interior. In some courts of the East End of London the CO_2 of the air amounts to 0·58 parts per 1,000 volumes and inside the houses to 0·85.

In towns no house should be of greater height than its distance from the opposite side of the street on which it may abut. There should be an open space not less than 10 feet broad in rear of the house extending throughout its entire length. No part of a building (except chimneys, etc.) should extend above a diagonal line drawn from the open space in the rear towards the house at an angle of 45° with the horizon.

Habitable rooms (except in the roof or underground) should be at least 9 feet 6 inches high in every part. Those in the roof should be of the same height throughout at least half the area of the room.

Each room should have windows opening into the external air, with a total superfices clear of the sash-frames equal to at least one-tenth of the floor area. Such windows should be so placed that direct sunlight may enter them, and so that at least half the upper part may open for ventilation, and the principal staircase in every dwelling-house should be lighted and ventilated directly into open air.

Under the Public Health (London) Act, 1891 (*q.v.*), an underground room may not be lawfully occupied as a bedroom unless it is constructed in accordance with certain stringent provisions as to width of outside area, ventilation, drainage, etc.

Artisans' Dwellings.—The Housing of the Working Classes Act, 1890, which embodies the Torrens, Cross, Shaftesbury, Housing of the Working Classes, the

Labouring Classes Lodging-houses Acts, 1851 to 1885, should be known.

The term 'density of population' refers to the proportion of population to a given part of the earth's surface. The smaller the houses in a district the greater will be the local density; thus, in Glasgow the average density is 84 persons per acre, while the local density varies from 25 to 348 (Dr. J. B. Russell). Such overcrowding leads to moral and physical degeneration. The smaller houses—one and two rooms—contain twice the amount of carbonic dioxide, four times the organic matter, and six times the number of organisms, than do the larger houses—four rooms and upwards (Haldane and Carnelley). It is not surprising, therefore, to find that of the children under five years of age who die in Glasgow, 32 per cent. die in houses of one apartment, and not 2 per cent. in houses of five apartments and upwards. Dr. Anderson, of Dundee, has drawn up a table (*Sanitary Record*, October 15, 1887), in which he compares the deaths in the whole population with those in houses of one, two, three, and four rooms and upwards. It shows conclusively that the fewer the rooms the higher is the death-rate.

The building of artisans' block buildings of good design on sites previously occupied by small, crowded houses has had this effect, that the general death-rate has been reduced, but from the opportunities afforded for increased contact between children on common stairs and landings there has been an increase in such infectious diseases as measles, diphtheria, whooping-cough, and scarlatina.

There is a choice between self-contained two-story buildings and the block system.

In two-storied houses privacy and absence of stairs constitute a great advantage, and where sufficient land is available they should be preferred to block buildings.

In the block system, if the same number of people are put into the same area, there should be a greater amount of open space around the dwellings, and thus more light and air obtained than in dwellings of the two-story type.

As a rule the blocks should not exceed four stories in height, and should be separated from one another by

a space equal to their height; as few families as possible should be brought into contact with one another on a flat or landing; staircases should be fireproof, about 4 feet wide, and broken by short landings, lighted by large windows, open to the external air. Glazed cement or bricks should be used to line the walls of staircases and landings. The water-closets and dust-shoots should be placed in projecting wings or offshoots from the main buildings. The fittings should be as simple and effective as possible. Soil-pipes should be external, properly ventilated, and ending in an inspection chamber, whereby obstructions may be readily removed. A sink, with water laid on, should be supplied to each dwelling, the pipe therefrom discharging over a gully into the open air. Washhouses are often placed on the roof, where soft-water may be stored. An essential of these buildings is a large playground for the children.

Perfect dryness of foundation, walls, and roof, and exclusion of ground-air, are necessary conditions of house construction.

The subsoil around the site, and, if there is much damp, also below it, should be drained, and, except where there is a rock foundation, the walls should be embedded in concrete, and under the whole house should be a layer of concrete 6 inches thick, having on the top a layer 1 inch thick of some impervious material, such as asphalte or cement.

In order to prevent damp rising from the ground a *damp-proof course* should be inserted in the wall just above the ground-level. Perforated slabs of glazed stoneware may be made to serve not only as a damp-proof course, but to ventilate the space under the floor. It is advisable to have a damp-proof course also where the rain-gutter joins the parapet, and in chimney-stacks just above the roof.

Basement walls are liable to become wet when in contact with a damp soil, even when there are drains and damp courses. In this case 'a dry area' must be formed by digging out or by building a second thin wall outside and a few inches away from the main wall, or by inserting slabs in a slanting position between the soil and the house wall, or the walls may be built hollow (with two

damp courses) and joined together with iron ties or bonding bricks, or the hollow may be filled with asphalte.

Walls exposed to driving rain or sea spray may be coated with slates, vitrified slabs, alkaline silicates, or cement; but such coating should continue down to the 'footings,' and should not be applied while the bricks are wet.

The walls of a newly-built house are damp from the water used in mixing the mortar, and also that absorbed by the bricks. If salt-water, sea-sand, or refuse lime from soap-works, containing glycerine, has been used in the mortar, it will never dry. Mortar should be composed of good lime combined with clean sharp sand, free from earthy matter (road scrapings or mould have sometimes been used by unscrupulous builders), or with crushed stone, slag, or well-burnt clay.

Walls are sometimes built of concrete made with cement. For internal walls, where space is limited, coke-breeze with cement has been used.

The settling of the walls sometimes breaks the drain passing underneath, if not properly protected by concrete or by the formation of an arched opening in the wall. It is usual to defer putting in drains until after the building has been carried up, with the view of allowing it to settle upon its foundations.

If there be no cellars the flooring ought to be raised 2 feet above the ground, which should be covered with cement and the space ventilated to prevent growth of the fungus of 'dry-rot.'

Walls and ceilings are usually covered with plaster, which should be of good materials ('jerry' builders have been known to use a mixture of lime and sifted mould or street refuse for this purpose). It should be finished with a smooth, non-porous surface. If a room is not to be papered, the walls should be coated with some form of cement or distemper, which sets hard and prevents percolation.

In cheaply-built modern houses the inner walls are often not carried up in brick beyond the first floor, and above this height are continued by a frame of wood filled in with lath and plaster.

Warming of Houses.

Heat is communicated by radiation, convection, and conduction.

Radiant heat is transmitted in straight lines in all directions by vibrations of the luminiferous ether. The intervening air is not warmed, but when radiant heat encounters a solid body it is partly reflected, partly absorbed, the amounts reflected and absorbed being in inverse proportions to one another, and depending on the surface, colour, and substance of the absorbing body, as well as upon the difference in temperature between the radiating and receiving bodies. The effect of radiant heat varies inversely as the square of the distance.

Convection of heat is that mode in which heat is conveyed in liquids or gases. These expand on heating, and, becoming specifically lighter, tend to rise, the volumes thus displaced being replaced by currents from the colder and heavier gas or liquid surrounding them.

By *conduction* heat passes from one particle of matter to another in contact with it, different substances having different thermal conductivities.

Private houses in England are generally warmed by means of fireplaces. The sense of warmth and comfort associated with open grates are due almost entirely to radiation, and very little to convection or conduction. The air of a room is to some extent warmed by convection currents from solid bodies which have absorbed radiant heat, but as the effect of radiation varies inversely as the square of the distance, it is only bodies in close proximity to the fire which receive any great amount of heat in this way. Indeed, five-eighths or more of the heat generated by an ordinary fire is carried by convection currents up the chimney and, for thermic purposes, wasted, the escaping air being replaced by draughts of cold air from outside. Some amount of heat is conveyed to the walls of a room by conduction.

Viewed simply as a means of heating, open fires are both costly and wasteful, and are quite unsuited to the warming of large buildings; but for private houses they are preferred in this country to any other method because of the cheerful light they emit, and the rapidity with

which bodily warmth can be absorbed from their radiant heat. Moreover, they constitute beyond question the healthiest method, as not only is no impurity added to the air, but the convection currents set up can be made to insure effective ventilation.

Thus, 1 lb. of coal requires about 300 cubic feet of air for its consumption, and an average grate consumes 8 lb. of coal in an hour—*i.e.*, 2,400 cubic feet of air. But in practice it is reckoned that 20,000 to 40,000 cubic feet of air are carried up the chimney by convection currents, so that the air in a room of 4,000 cubic feet would be changed from five to ten times per hour according to the strength of the fire. If the incoming air be pure atmospheric air this more than suffices for ventilation, but the room is not thoroughly and equably warmed.

Many attempts have been made to devise a grate which shall economize some of the large percentage, estimated at 87 per cent., of the fuel practically wasted in ordinary grates.

The best form is the 'rifle-backed grate,' on the principles devised by Pridgin Teale. The essentials of a good grate as laid down by him are as follows: The fireplace should project well into the room so as to favour radiation; the back, bottom, and sides should be of fire-brick rather than metal to increase absorption; the back of the fireplace should lean or hang over the fire, so that the flames may play on it, the throat of the chimney being contracted so as to narrow the draught; the bottom of the fire should be deep from before back; the bars in front should be narrow, and all slits in the bottom of the fire should be as narrow as possible, and the space beneath the fire should be closed in front by a close-fitting shield or economizer, so as to secure as complete combustion as possible of the fuel at the bottom by the exclusion of cold air; the diameter of the chimney should not be in excess of ventilation requirements; 'under-feeding'—*i.e.*, the introduction of fuel at the bottom instead of the top—may be resorted to; reflection may be utilized by surrounding the grate with a bright reflecting surface of polished metal or encaustic tiles.

Galton's air-grate (largely used in military barracks) aims at combining radiation and convection. Air is in-

troduced by a special flue directly from the outside (the flue passing under the floor if the fireplace be built upon an internal wall) into an air chamber surrounding the back and sides of the grate. Wrought-iron flanges from the back of the fireplace project into this air-chamber, and the air passing over them is warmed and introduced into the room by an opening above the fireplace. Upper rooms may be made to receive warm air from the warm-air flue if desired. Boyd's Hygiastic grate is constructed on the same principle. Ventilating grates are said to reduce the wasted heat by one-fourth, but do not yield such cheerful fires as open grates.

It is important that the air which ventilates a room shall be pure atmospheric air. In some houses the warmth of fires sucks in ground-air from the basement or even sewer-air into the rooms.

Stoves are of two kinds, closed and ventilating. Closed stoves, which are economical of fuel, are largely used on the Continent. They warm the air effectively by convection, but are attended with serious drawbacks: (1) They do not contribute to ventilation, and the air becomes exhausted and 'stuffy'; (2) they tend to render the air unpleasantly dry (the relative humidity of the heated air being greatly diminished), though this may be to some extent obviated by exposing water to evaporation in shallow pans; (3) the air being generally at a higher temperature than the floor and walls of the room, 'chills' are often experienced, the bodies of the occupants radiating their heat to the cold surfaces around them, while the defensive forces of the body against chill are relaxed by the enervating warmth of the stove-heated air (Kenwood); (4) if the stove becomes overheated the organic impurities in the air are charred by contact with the heated surface, and a close, unpleasant smell is occasioned; (5) incomplete combustion is apt to generate carbonic oxide, and give rise to fatal poisoning. This danger is specially connected with cast-iron stoves. Hence, stoves should be either lined with fire-clay or made entirely of fire-clay and china.

A favourite method of suicide in France is by 'charcoal'—*i.e.*, by closing up all the apertures, and going to sleep in a room heated with charcoal in a cast-iron stove.

The victim dies of carbonic oxide poisoning in his or her sleep.

Several fatal cases of carbonic oxide poisoning have occurred in England from the incautious use of Geyser stoves (coiled water-pipe sheated by gas) in unventilated bath-rooms.

Ventilating stoves are constructed with air chambers, gas or coal being used to warm the incoming fresh air. In gas-stoves clay-balls, asbestos fibre, perforated fire-bricks, etc., may be rendered incandescent by means of Bunsen burners, or a reflected surface of polished metal may be employed, which reflects a cheerful glow. With these methods it is absolutely necessary to have a flue, but this need not be so large as the chimney required by coal fires.

'Condensing' gas-stoves form another class suitable for entrance halls, corridors, and for rooms, so long as a sufficiency of ventilation (3,000 cubic feet of fresh air per head) is supplied to those using the room. The heat is obtained from an Argand burner, the products of combustion and hot air circulate through a number of flues round which the fresh air plays, and, finally, the water vapour, which is one of the products of gas combustion, is condensed by passing through upright tubes, and caught in a tray beneath, carrying down with it most of the sulphur products, but not the carbon dioxide. A flue is therefore required with this form. Oil may be used instead of gas in this way, but if a good oil be used, 'condensing' does not appear necessary. Combustion must, however, be perfect.

Hot water or steam afford an easily controlled method of heating. Hot-water pipes are of two kinds—'high pressure' and 'low pressure.'

High-pressure pipes (Perkins' patent) are of small calibre with thick walls. One portion of the tube passes through a fire. There is no boiler; the water is heated to 300° or 350° F.

Low-pressure pipes are attached to a boiler; the water is not heated above 200° F. In dwelling-houses 12 feet of four-inch pipe is allowed for every 1,000 cubic feet, and will warm to 65° F. The length of high-pressure pipe required is about two-thirds the above.

Steam-piping is equally good if waste steam can be utilized.

The 'whole-house' system of heating, if carried out with proper ventilation, is a good plan. All the fresh air entering a house is passed round a stove in the cellar, and then conducted by pipes to the entrance hall and rooms; or if there is no cellar a calorigen or slow-combustion stove is placed in the hall, which becomes a reservoir of warm fresh air for the rest of the house.

Inspection of Houses, Etc.

In Examining a House.—On entering inquire as to number of inmates and how distributed, trace all pipes down from roof and find out their use and termination examine cisterns, examine how the water is laid on and method of supply, and arrangements for disposal of refuse and excreta.

Note size of rooms and their position, and compare the air-space and means of ventilation with the number of people inhabiting them.

Examine the general surroundings.

The following schedule, based on that suggested by Dr. Whitelegge, will serve as a useful model:

Address.

Occupier.

Owner.—Name and address.

Site.—Elevation, aspect, slope. Proximity to hills, valleys, water-courses. Nature of soil. Dryness.

Surroundings.—House detached, semi-detached, in a row, back to back. Access of light and air. Obstruction by trees, high grounds, or other buildings. Open space at front, back, sides (stating area). Proximity (stating distance in feet) of stables, cowsheds, pig-sties, manure pits, foul ditches, stagnant water, offensive accumulation, offensive trades, or other sources of effluvia.

Yard and Outbuildings.—Condition as to cleanliness, paving, drainage.

Foundations.—Damp-proof course, dry area, banking

of soil against walls. Dryness of basement. Exclusion of ground-air. Ventilation of space beneath ground-floor.

Walls.—Materials, thickness, carried up to roof? Dilapidations. Evidence of damp at any part. Source of such damp.

Roof.—Construction. Soundness.

Floors, Staircases, Windows, Doors, and Ceilings.—Soundness.

Rooms.—Number on each story, including basement.

Length, breadth, and height Windows. Total window space. Space made to open. Opening top and bottom? Other means of ventilation. Chimney	of each room.*

Drainage—

Sink wastes Bath wastes	Construction and course of waste-pipes.
Lavatory wastes Floor gullies	Description and efficiency of traps. Disconnection.

Soil-pipes. Construction, dimensions, position, course, ventilation.

Gullies. Construction and trapping.

Gutters round eaves. Efficiency.

Rain-pipes. Course, trapping, disconnection, destination. Leakage?

House drains. Course, construction, dimensions, gradients, ventilation, means of access, disconnection from sewer. Flushing, cleanliness. Soundness, as tested by smoke, peppermint water, etc. Drains under basement.

Cesspool (if any).—Position, construction, dimensions, ventilation, overflow, water-tight?

Closets.—Number, position, cleanliness, lighting, ventilation. Proportion of persons to each closet. If more than one house using closet, note the number. If outdoor, note distance from nearest door or window.

* *As regards sleeping-rooms in basement*, certain further details are necessary—namely, depth of floor below level of adjoining street; width, depth, and lateral extent of area in front; depth of drain below floor; position of window in respect to steps, if any, bridging across open area.

Kind of Closet.—As water, trough, slop, or hand-flushed. Kind of apparatus, efficiency. Source of water-supply, sufficiency of flush.

Pail, pan, tub, or box-closet. Size of receptacle, material, floor level, means of access. With or without ashes or other admixture?

Privy-midden, privy with cesspit, earth-closet. Dimensions of receptacle, relation of floor to ground-level, materials, water-tight, covered, arrangements for applying ashes or earth to excreta. Connected with sewer? Position.

Household Refuse.—Means of storage.

Scavenging.—Mode, frequency and efficiency of removal of excreta and household refuse. By whom performed?

Water-supply.—Public or private (constant or intermittent), from mains (by tap or standpipe), spring, stream, canal, dip-trough, well, rain-water cistern; distance from house, constancy, efficiency, purity. Note any obvious risk of pollution. If from well, note depth, construction, lining, cover; distance in feet from the nearest possible source of pollution, or filth accumulation of any kind.* If from cistern, note position, construction, cover, cleanliness, connection with water-closet, discharge of overflow pipe.

Cleanliness of Premises.—Light. Ventilation.

Animals Kept.—Description. Number. Where kept. Nuisance resulting.

Inmates.—Number of residents. Age, sex, occupation of each. Number of families; distinguishing tenement occupied by each. Number sleeping in each room if there is a suspicion of overcrowding. Number sleeping in basement.

* In examining a *river* begin at the highest point, observe the condition of the water there, then work down the stream. Note (1) the state of the river as regards current, clearness, smell, weeds, mud, etc.; (2) pipes opening into river and what they discharge; (3) buildings on the banks, as factories, stables, pig-sties, etc.

CHAPTER VI.

SCHOOL HYGIENE AND EXERCISE.

School Hygiene.

Apart from the general principles of hygiene, which ought to be brought to bear on the erection of school premises and on the personal treatment of the scholars, there are other special matters to which attention may be drawn.

Overpressure.—The true aim of all education is the production of a well-balanced mind in a healthy body. To this end it is necessary that the powers of observation, reflection, and memory be developed, and that such knowledge as shall be of practical use in life be imparted, while at the same time the physical and moral parts of a child's nature are not neglected, but are properly trained and regulated. The so-called education which 'crams' a child's head with as many facts as will enable him to pass an examination, or earn a 'grant,' is worse than useless; for knowledge so acquired is quickly lost, and the brain is unfitted for proper mental work, and it forms an important cause in the production of the condition known as 'overpressure,' a condition characterized by headaches, talking in the sleep, irritability, restlessness, inability to fix the attention, and sometimes by sickness.

Sir J. Crichton-Browne, who reported on overpressure in Board schools, found that 40 per cent. of the children suffered from headaches and other symptoms, which he regarded as evidence that proper adaptation did not exist between the children and their work. The factors, however, in the production of these symptoms are numerous, and may be referred to such causes as the following, besides the strain of preparing for examinations: Home-lessons; bad arrangement of work, necessitating too continuous attention to one subject; punishments by impositions, keeping-in, or caning. A much less amount of mental strain will affect children who have not sufficient exercise; who live in insanitary conditions and breathe

impure air; who are in delicate health, or growing rapidly, or who are convalescent from illness; who suffer from want of food or indigestion; who have defective eyesight or ear-troubles. Overstrain tells more on girls than on boys. In the future consideration will be given to some method of classification, whereby age, sex, physical health, individual mental receptivity and idiosyncrasy, and probable career of the children, may be taken into account. The adoption of the Kindergarten system in infant schools is a move in this direction, as in the early years of life the cultivation of the senses and powers of observation and construction is of more importance than the premature stimulation of the powers of reflection and memory.

So dependent is the capacity for attention to and the learning of lessons upon a proper condition of bodily health that (in the words of Dr. B. W. Richardson and Sir Douglas Galton) it is essential in the interests of the community at large that children should not be forced to attend school unless they are in such a physical condition as to be able to take advantage of, and not be injured by, the teaching. Hence, in these days of compulsory education it is necessary that the greatest attention be paid to the hygienic conditions of schools, and to the physical state of the scholars.

It is contended by many that compulsory education should be supplemented in the case of children of the poorest classes by a gratuitous supply of proper clothing and food, and even for the children of parents who are better off the supply of a good meal for a small sum may be thought desirable.

Physical recreation is a question to which too little attention is paid by those engaged in educational work. The outdoor games of boys may be easily directed and controlled, but with girls the use of systematic physical exercises is rendered necessary in order to bring all parts of the body into play without any part being overtaxed.

Eyesight.—The heavy demands made by school life on the eyesight render it essential that everything should be done to make its use as easy and free from undue or prolonged strain as possible. Unfortunately, however, statistics show that this is not done, and that not only

are hereditary conditions aggravated, but that to a large extent myopia and other defects in vision are produced. The influences tending to produce these defects may be classified under the four following heads:

1. *A low state of the general health.*

2. *Prolonged Straining of Accommodation.*—In reading or writing the books or slates should not be nearer the eyes than 12 or 15 inches; the distance is often much less than this by reason of the improper posture which has to be assumed on account of the unsuitableness of desks and seats, the use of which also leads to spinal curvature, badly-developed chests, etc.

'Benches and desks, graduated according to the ages of the children, should be provided for all the scholars, and placed at right angles to the light' (Day-school Code, 1894).

Where possible, each pupil should have his or her own desk and seat. For reading and writing, the desk and seat should be so arranged that a perpendicular line dropped from the edge of the desk should impinge on the edge of the seat. The difference between the height of the seat and the desk should be about one-sixth the height of the scholar. The desk should slope at angles of 15° to 30° for writing, and 40° to 45° for reading.

The height of the seat from the ground should correspond to the length of the scholar's leg from the sole of the foot to the knee; the breadth should not be less than 8 inches. It should be horizontal and cane-bottomed; there should be a back to the seat, and the top of it should be for boys 1 inch lower and for girls 1 inch higher than the edge of the desk. The support given by it should be just below the shoulder-blades of the occupant of the seat (Liebreich); there should be a support for the feet placed at an angle of 30°.

At least 18 inches per child should be allowed in the length of a desk. Desks should not be longer than 12 feet, and they should not be placed more than four deep. Dual desks (3 feet 4 inches long) may be placed eight deep.

3. *Inadequate or Ill-directed Light* (*not only in school, but also at home*).—The amount of window area necessary

for any room must vary with the situation of the windows and other external conditions. Cohn advises that it should equal one-fourth of the floor space, while R. Morris gives this formula as a means to determine it: Area of windows $= \sqrt{\text{length} \times \text{breadth} \times \text{height of room}}$; but in any case every part and corner of a school should be fully lighted. The best direction for light to enter is from the left. Cross-lighting is desirable if the light from the left be the stronger, as the intensity of the illumination is thereby greater, and the windows being opposite is a great assistance in ventilation. The height of the windows from the floor should never be less than 5 feet; light obtained from a lower point is too horizontal and dazzling to be of use. The best light comes from the highest point, and therefore windows should be carried up nearly to the ceiling. 'All kinds of glazing which diminish the light and are troublesome to keep clean and in repair should be avoided. A large portion of each window should be made to open.' Artificial light is detrimental to the eyes, especially when no measures are taken to carry off the heat and other products of combustion.

4. *Unsuitableness of Materials used in Teaching.*—All printing and writing should be clear and distinct. No type smaller than pica should be used, and the spaces between words and lines should be relatively wide. Paper should be of a cream colour or pale blue tint and unglazed; pale ink, greasy slates, and shining blackboards are particularly trying to the eyes. Needlework should not be too fine, nor the sewing lesson too long. Good daylight is essential. A good colour for the material is blue.

Deafness is responsible for some of the backwardness of children, for, as a result of the examination of over 9,000 children in this and other countries, it is stated that no less than 26 per cent. have some defect in hearing, and are therefore at a disadvantage compared with those hearing normally; and not only so, but the cerebral functions may be hampered by congestions of the veins and lymphatics of the head caused by growths affecting the ear and throat.

Aprosexia is a term which has been given by Guye of Amsterdam to the condition of inability of school-children to fix their attention and other allied neuroses due to obstructive conditions of the naso-pharynx.

Children with discharges from the ear ought not to attend school.

Children whose progress is unsatisfactory, or who are inattentive, dull, or idle, should have their throats and ears examined.

Such children should be placed near the teacher with the better ear towards him.

Stringent orders should be given prohibiting boxing the ears.

Female teachers in noisy localities, or with too large classes to look after, have to strain their voices to make themselves heard, and chronic laryngitis is frequently set up thereby.

Dr. Barr of Glasgow, in a paper read before the British Medical Association in 1889, made some useful suggestions:

'The site of a school should be removed as far as possible from noisy works and main thoroughfares. Class-rooms should not open directly off main staircases; walls separating class-rooms from one another or from staircases should be of such material as to form bad conductors of sound. Class-rooms should be oblong, 20 or 25 feet by 15 feet; the number of scholars in one room should not be more than fifty; there should not be less than 15 square feet of floor area (150 cubic feet) per pupil.'

The Education Department requires 10 square feet per child (or 8 square feet for infants in the first standard), with walls from 12 to 14 feet high. This allowance is calculated for each unit of average attendance.

For ventilation about $1\frac{1}{2}$ square feet for outlets and rather more for inlets is desirable. Outlets should, if possible, have motive power by heat or exhaust to prevent their acting as cold-air inlets.

Warming of class-rooms and corridors should be moderate and evenly distributed, so as to maintain a temperature of from 56° to 60°; 65° is a good temperature for infants. Where hot-water pipes are used, open grates

are always a desirable addition to promote ventilation. Water-closets should be at a short distance and completely disconnected from the school, where possible. Each closet must be separated, fully lighted and ventilated, properly screened, and supplied with a door, with only one seat to each closet. The number to be provided must vary with the size and composition of the school, 15 per cent. for girls and infants, 10 per cent. for boys, with urinals (about 5 per cent.) in addition. Trough closets are commonly employed, and should be flushed automatically at least every hour during school hours, and oftener during the time children are allowed in the playgrounds. But short-hopper closets have been provided with satisfactory results in many schools.

Open play-grounds, level, airy, and properly drained, at least 30 square feet for each child, should be provided.

The New York Board of Health has suggested that the following precautions should be enforced :

1. The use of slates, slate-pencils, and sponges shall be discontinued in all the public schools. 2. According to requirement, pupils shall be supplied with pencils and pen-holders, each pupil to retain those received in a box provided for the purpose, such box to be marked with the pupil's name. Pencils and penholders shall not be transferred from one pupil to another without suitable disinfection. 3. All school property left in the school building by a child sick with any contagious disease, and all such property found in a compartment occupied by one of a family in which a case of small-pox, typhus fever, diphtheria, scarle fever, or measles has occurred, shall be taken by the health department for disinfection or destruction. 4. Books which are taken home by pupils shall be covered regularly once each month with brown manilla paper. 5. Places for drinking-water on the ground-floors of the school-buildings shall be discontinued, and a covered pitcher provided for each class-room, in which fresh water shall be placed before every session. A numbered cup, to be kept in the class-room, shall be issued to each pupil. No interchange of cups shall be allowed.

Dormitories in Poor-Law schools must have 360 cubic feet of space, of which 36 square feet must be floor area,

per occupant. In boarding-schools Dr. Dukes recommends 800 cubic feet and 70 feet floor area as minimum requirements.

In Poor-Law schools special precautions are required to prevent the spread of infectious and contagious diseases, particularly ophthalmia, ring-worm, etc. On sociological grounds objection has been raised to the moral taint of pauperism that clings to barrack-schools. Many have advocated in preference the boarding-out system, either in labourers' houses or in cottages built for the purpose, each under the charge of a foster-mother. Apart from difficulties of management connected with the boarding-out system on a large scale, it is probable that on the whole a better education can be given in large schools if properly conducted.

Holiday Colonies.—The plan of sending poor children to country cottages for two or three weeks at a time is fraught with much permanent benefit to the children. It is found that after three weeks' stay in the country, town-bred children not only gain rapidly in height, weight, chest-development and general health, but the improvement is maintained for a considerable length of time after their return.

Compulsory closure of a school is sometimes necessary, as during severe epidemics, or when drains, etc., in or near the school are being repaired. This can be effected, not under the Public Health Act, but by means of Art. 88 of the Day-school Code, 1894, wherein it is provided that managers of public elementary schools must comply with any notice of the sanitary authority of the district in which the school is situated, or any two members thereof acting on the advice of the medical officer of health requiring them for a specified time, and for a specified reason (with a view to preventing the spread of disease or any danger to health like to arise from the condition of the school), either to close the school or to exclude any scholars from attendance. This does not apply to Sunday or private schools.

It is very desirable that teachers should have some instruction in the laws of health, and that they should have sufficient knowledge to suspect the presence of infectious or contagious maladies in a school; they should

know how soon, on an average, a child who has had an infectious disease may be allowed in school again.

Exercise.

The regular action of the voluntary muscles, which is known as **exercise,** is necessary for the maintenance of good health. Without it the involuntary muscles, especially the heart and other organs, are much interfered with in the performance of their functions.

Effects of a Proper Amount of Exercise.—The oxidation of carbon is increased, chiefly in the muscles, and it is eliminated with an increased amount of watery vapour from the lungs. The circulation becomes more rapid, and greater pressure is produced on the vessels; hence there is a quicker removal of effete matters, and a more rapid renewal of tissue. Oxygen is necessary for muscular exertion, and, as its absorption is dependent on the amount and action of the nitrogenous structures of the body, more nitrogenous food is required with increased muscular work, else the growing muscles will rob other parts of the body (Pettenkofer and Voit's observations). For every additional foot-ton of visible work, 1 grain of nitrogen should be added to the food.

It is believed that during periods of rest oxygen is stored up in the muscles, and it is from this source that the greatest amount is drawn during action.

Excessive or misdirected exercise may lead to pulmonary congestion and hæmoptysis; to cardiac rupture, palpitation, hypertrophy, and occasionally valvular disease, to injuries to bloodvessels, and to exhaustion of the muscular system; this latter is due to the accumulation in the muscles of the products of their own action, especially paralactic acid, and to exhaustion of the supply of oxygen.

Deficient exercise favours spinal curvature, tubercular disease of the lungs, cardiac debility, dilatation and fatty degeneration; lessens the appetite, enfeebles the digestive power, and produces congested conditions of the abdominal organs; the nervous system becomes morbidly excitable; it appears to lead in two or three generations to degenerate mental formation.

Amount of Exercise.—To enable comparisons to be made between different kinds of exercise, the 'foot-ton,' or 'foot-pound,' has been adopted as a unit whereby to express the amount of work done. One hundred foot-tons means that 100 tons are lifted 1 foot in a certain time. Sometimes pounds are used instead of tons, and in France it is expressed as so many kilogrammes lifted 1 metre.

Three hundred foot-tons is an average day's work for a healthy, strong adult; 400 foot-tons is a hard day's work. The internal work of the heart and muscles of respiration is equal to about 260 foot-tons, that for the heart varying from 122 to 277, and for respiration being about 11 foot-tons in twenty-four hours.

In calculating the work done by walking or climbing exercise, the following formula is employed:

$$\frac{(W + W^1) \times D}{20 \times 2{,}240} = \text{foot-tons.}$$

W is the weight of the person; W^1 is the weight carried; D is the distance walked in *feet;* 20 is the coefficient of traction, and is obtained from calculations showing that walking on a level surface at the rate of 3 miles an hour is equivalent to raising one-twentieth part of the weight of the body, etc., through the distance walked; 2,240 is the number of pounds in a ton. To get the distance in feet, multiply 5,280 by the number of miles walked. Three miles an hour appears to be the rate at which the greatest amount of work can be done at the least expenditure of energy. Work becomes heavier and more exhausting if done in a shorter time—that is to say, velocity is gained at a disproportionately increased expense of the amount of work.

From a consideration of the effects of exercise on the body, the late Dr. Parkes deduced the following rules:

1. During exercise there must be no impediment to the freest play of the chest and respiratory muscles, else the removal of CO_2 will be checked. When breathing becomes laborious, with sighing, rest is necessary.

2. Food containing carbon and nitrogen must be increased with extra work. Carbon is best given in the form of fat.

3. Alcohol lessens the excretion of pulmonary CO_2, and deadens the action of the nerves of volition, and hence prevents great or continued exertion.

4. As excretion of CO_2 is increased, a large amount of pure air is required ; in covered buildings ventilation must be carried out to the greatest possible extent.

5. In commencing unaccustomed exercise, the action of the heart must be closely watched ; the chief object of special 'training' is to get a concordant action established between the heart and the bloodvessels.

6. The skin should be kept extremely clean ; during exertion it may be thinly clothed, but immediately after, or in the intervals of exertion, it should be covered sufficiently well with flannels to prevent the least feeling of coolness of the surface. The evaporation from the skin is nearly doubled, and the temperature is kept normal thereby ; any interference with it causes langour, and as it continues after exertion ceases, there is great danger of chill if extra clothing is not applied. After active exercise a good bath is useful to remove sweat, chloride of sodium, fatty acids, etc., which accumulate on the skin.

7. Water is absolutely necessary during and after exercise ; it is better to take small quantities frequently during exercise than a large amount afterwards, when it might be dangerous from its sudden cooling effect. The precaution may be taken of holding the cold water in the mouth for a short time before swallowing.

8. Exercise should be adapted to the physical constitution, and should develop the whole system, and not be confined to certain groups of muscles, which after enlarging will, if over-exercised, commence to waste. The periods of life when extra exertion should be taken with caution are between the ages of fifteen and seventeen, when the most rapid growth takes place, and later in life, when the arteries become atheromatous. The Swedish system (Ling's) of gymnastics is well fitted to properly develop all parts of the body ; but, as already pointed out, exercise in a covered building, as in gymnasia, should never be allowed to supersede outdoor sports. Exercise should be systematic and regular, and never sudden and violent ; it should not be taken directly after meals.

CHAPTER VII.

CLIMATE AND METEOROLOGY.

CLIMATE originally expressed the annual temperature of a place when temperature and latitude were supposed to correspond, but it is now regarded as the sum of the influences connected with solar agencies, the soil, the air, the water (Parkes), or as the condition of a district in regard to certain meteorological factors, notably, air, temperature, moisture, atmospheric pressure and electricity, viewed in their effects upon animal or vegetable life (Moore).

Weather is the sum of the variations from time to time in respect of all or any of those conditions.

Temperature.—Climates are divided in classes according to temperature, as tropical, temperate, arctic; into equable and extreme, etc. The temperature of any place depends upon:

1. Geographical position as influencing the amount and duration of the sun's rays.
2. Relative amount of land and water. Land absorbs heat, and gives it out more rapidly than water.
3. Elevation. Temperature declines about 1° F. for each 300 feet of ascent. Atmospheric density is diminished and humidity reduced.
4. Aspect, exposure and special conditions.
5. Aerial and ocean currents (warm and cold).
6. Nature of soil.
7. Barometric pressure.
8. Rainfall.

Changes in the temperature of any place are either *periodic* or *non-periodic*. The former depend on day and night, and on the seasons or position of the place in respect to the sun; such changes are also called *fluctuations*; they are largely influenced by the distance from the sea and the presence or absence of high lands. The *amplitude* of the daily or yearly fluctuations represents the difference between the day and night temperatures, or between the hottest and coldest month. The terms

limited and *extreme* are applied to the amplitude of the yearly fluctuations. The terms *equable* and *excessive* are applied to non-periodic variations. Equable, limited, or insular climates have slight yearly and daily variations. Extreme, excessive, or continental climates have great variations.

The *range of temperature* is variously expressed :

Extreme daily range in the month or year is the difference between the maximum and minimum thermometers in any one day.

Extreme monthly or annual range is the difference between the greatest and least height in the month or year.

Mean monthly range is the daily range added and divided by the number of days in a month (or the difference between the mean of all the maxima and the mean of all the minima).

The *yearly mean range* is the monthly ranges added and divided by twelve. The mean of the month of October and of the last fortnight of April will give an approximation to the mean of the year.

Isothermal Lines.—These are lines drawn on maps passing through the spots which have the same mean annual temperature ; but this gives no information of the fluctuations in temperature. A better idea can be obtained from maps which give lines representing the mean monthly range ; maps are also constructed giving the mean summer (*isotheral*) and the mean winter (*isocheimonal* or *isocheimal*) temperatures.

Pressure of Air.—At sea-level the weight of a column of air is nearly 15 pounds on every square inch ; for each 900 feet of ascent above the sea-level the weight decreases about half a pound.

The weight of a cubic foot of dry air at 32° F. and normal pressure is 566·85 grains ; it is affected by temperature and humidity. Air expands with heat $\frac{1}{491}$ part of its volume for every degree Fahrenheit, and therefore weighs less bulk for bulk.

Air also expands when it takes up moisture, so that, instead of being heavier from the addition of watery vapour, a cubic foot of moist air weighs some grains lighter than one of dry air.

These variations in the condition of the air affect the column of mercury in the barometer, so that when the height of the barometer is known, with the temperature and amount of humidity, the weight of a cubic foot of air can be ascertained.

The pressure of the atmosphere is sufficient to raise a column of mercury in a vacuum to a height varying between 28 inches and 31 inches, the average or standard pressure being at 29·922 inches (760 millimetres).

Other fluids, as water and glycerine, are sometimes employed in the construction of barometers. The height to which they would be raised may be ascertained by a simple proportion sum, comparing the specific gravity of the fluid used with that of mercury, thus :

Sp. gr. H_2O.		Sp. gr. Hg.		Height of Column of Hg.		Height of Column of Water.
1·0	:	13·594	::	30 in.	:	x (33·99 ft.)

Water barometers having a column of 34 feet are obviously very sensitive, but are unfit for general use, owing to the ~~high~~ lower freezing-point of water and liability to condensation of its vapour. Undiluted glycerine (Jordan's barometer) is more practically useful, not being liable to freezing or evaporation. The specific gravity of glycerine is 1·26, and the length of the column 27 feet.

To read a standard (Fortin's) mercurial cistern barometer : First ascertain the temperature, then raise or lower the bottom of the cistern so that the ivory point (known as the fiducial point) just touches the surface of the mercury, which will then be of a uniform height ; then the figures on the scale in a line with the top of the column of mercury are to be read. This scale is divided into inches, tenths and half-tenths ($\frac{5}{100}$), but in order to take observations with greater nicety a *vernier* is employed. This is a small scale divided into 25 equal parts, which are equal to 24 half-tenth divisions on the barometer scale ; hence each division on the vernier is $\frac{1}{25}$ less than a half-tenth division—that is, $\frac{2}{1000}$ of an inch (0·002 inch).

To use the vernier : Read off the fixed scale to a half-tenth (0·05 inch), then adjust the vernier so that its lowest line is level with the top of the column, see what line corresponds exactly to a line on the fixed scale, and

count the number of divisions from the bottom of the vernier ; multiply this number by 0·002, add this to that read off the fixed scale, and the result is the exact height of the mercury. Corrections have to be made for height and temperature. The Kew certificate gives corrections necessary for index error, capacity, and capillarity.

The *aneroid* or holosteric barometer is a form in which the pressure of the atmosphere acts on the elastic top of a thin metal box, from which the air has been displaced by peroxide of hydrogen. By an arrangement of levers the movements of the metal are made to turn an index on a dial face. This form of instrument is sensitive and convenient, but is liable to get out of order owing to rust, loss of elasticity in the spring, etc. Its readings should be compared from time to time with those of a standard mercurial barometer.

Effects produced by Considerable Differences of Pressure—*Lessened Pressure.*—The physiological effects begin to be perceptible at about 3,000 feet of altitude. At great heights, if the ascent has been sudden, there is increased pressure of the gases in the body against the containing parts, the superficial vessels swell, and there may be bleeding from the nose and lungs.

To avoid this physiological disturbance ('mountain sickness'), mountaineers ascending great heights, as in the Himalayas, are obliged to camp for a day or two at successive altitudes, so as to become acclimatized to the rarefied air.

Residence at altitudes between 4,000 feet and 7,000 feet produces improvement in digestion, sanguification, and in nervous and muscular vigour (Hermann Weber). The conditions which produce this beneficial effect, as well as the curative result in cases of phthisis, are :

1. The atmosphere is calm and still.
2. The air is greatly rarefied.
3. It is extremely dry.
4. Solar radiation is considerable.
5. The air is free from dust and organisms.

The smaller amount of oxygen in the rarefied air is counteracted by the greater purity found at high altitudes

as compared with lower ones; while it is found that the respirations are increased both in frequency and depth, and that eventually there is enlargement of the thorax from hypertrophy of healthy lung-tissue.

That the air is not antiseptic, as has sometimes been claimed, is shown by the presence of infectious diseases from time to time in the dirty, ill-ventilated châlets of the peasantry.

Increased pressure decreases the pulse-rate, the number of respirations and evaporation, with increased secretion of urine; work can be carried on vigorously, but if the pressure be increased to equal more than two or three atmospheres, heaviness, headache, and convulsions may be produced from the increased absorption of oxygen.

It has been observed that when persons who have been working in diving-bells, in 'caissons' (compressed air-chambers for working under water), and in deep mines, come suddenly up to the surface, they are liable to suffer from hæmorrhages and subsequently from nervous affections.

Such workers have been known to prefer remaining continuously in a diving-bell for several days rather than face the discomforts of coming to the surface after the day's shift.

Barometric variations are of two kinds, regular and irregular.

The regular and periodic are:

1. Diurnal—two maxima of pressure at 10 a.m. and 10 p.m., two minima at 3 a.m. and 3 p.m.
2. Annual—due to the relation of the sun to the earth, and the amount of watery vapour in the air.

The irregular or non-periodic are:

1. Cyclonic.
2. Anti-cyclonic.

They are measured or determined by drawing lines of equal barometric pressure (*isobars*) on a map of the area under discussion, which is then called a synoptic weather chart. These isobars are drawn for each tenth of an inch. They tend to assume two primary and five secondary shapes. If they enclose an area of *low* pressure forming a circle or oval they are described as *cyclonic*. If, on the contrary, the isobars encircle an area of *high* pressure,

they are described as *anti-cyclonic*. The five secondary shapes are, for the most part, modifications of the primary types, or connected with either one or other of them.

A *secondary or subsidiary depression* is produced when one or more of the isobars in a cyclonic system curve outwards from the centre, forming a loop embracing a secondary area of low pressure in the periphery of the primary cyclone.

V-shaped depressions are produced when the isobars, instead of curving into a cyclone, bend in the shape of the letter V. These sometimes jut out between two anti-cyclonic systems, in the same way as a tongue of high pressure (called a *wedge*) is inserted between two areas of low pressure following rapidly on one another.

Straight isobars are occasionally formed when the isobars run parallel to each other.

A *col* is a furrow or neck of relatively low or less high pressure connecting two anti-cyclones, so called because it is analagous to the col which forms a pass between two adjacent mountain peaks.

Contrasting the two systems, Dr. Moore says :

1. Cyclonic areas as a rule travel, it may be, at the rate of 20 miles an hour or upwards ; in equatorial regions from east to west, in extra-tropical latitudes usually from west to east. Anti-cyclonic systems, on the contrary, are often stationary for days or weeks, or their motion is slow and irregular. They frequently move away from the track of cyclonic systems at right angles.

2. In cyclonic systems the isobars generally approach each other much more closely than do those of anti-cyclones ; in other words, the gradients* are steeper, and therefore the winds are stronger, in cyclones than in anti-cyclones.

3. Unsettled, windy, rainy, or showery weather is commonly associated with cyclonic systems.

In anti-cyclones conditions are, as a rule, fine, quiet,

* Barometrical gradients are expressed at the British Meteorological Office in decimal parts of an inch of mercury per fifteen nautical miles (about seventeen statute miles). They are regarded as slight or moderate when they are below 0·01 inch, but steep when they exceed 0·02 inch. They seldom exceed 0·04 inch or 0·05 inch in the British Islands.

and dry. In summer the days are hot and the nights cool (except in the N.W. quadrant of the system, where the nights are often warm and cloudy). Where the calm centre overlies the sea fogs are prevalent.

In winter there is intense frost in the centre and southern quadrants of the area with clear sky; in the northern parts conditions may be milder. Dense fogs may accompany the calms of an anti-cyclone, with clouds and drizzling rain towards the periphery.

The term *intensity* in reference to a cyclonic system means that the isobars are close together, and that the system is deep (steep gradients) and moving quickly. Storms accompanying such are severe, but of short duration. When applied to an anti-cyclone it means that the barometer has reached an unusual height in its centre, and that the system is of vast extent and of long duration.

4. Thunderstorms are very apt to develop in connection with V-shaped and secondary depressions, the former being accompanied by violent shifts of wind and sudden changes of temperature, with heavy squalls and showers of rain or hail, or, in winter, snow.

Wind.—Movements of the atmosphere are primarily from west to east, and are due to the unequal distribution of heat over the earth's surface.

'Wherever the air becomes heated on the earth's surface it expands, and the barometer falls. Wherever the air is chilled it contracts, and the barometer rises'; the heavier cold air is thus forced towards the warmer area. Variations are produced in the current by the movement of the earth, and by various local circumstances.

In an anti-cyclone the tendency of the wind, near the earth's surface, is spirally outwards from the centre, in the same direction as the hands of a clock; in a cyclone spirally inwards towards the centre, in the reverse direction to the hands of a clock. This tendency is formulated in Buys' Ballots' Law: 'If you stand with your back to the wind the lowest pressure lies to your left and in front.'

Cyclones follow the course of the prevailing winds; hence, as west winds are prevalent in this country, we are able to get 'storm-warnings' from America when a 'depression' is moving towards us.

There is evidence of an eleven-year periodicity in regard

to cyclones and rainfall coincident with the number of disturbances in the sun (as shown by 'sun-spots'). In maximum sun-spot years storms are of much greater frequency and intensity than in years when the sun-spots are at a minimum.

Winds are of the greatest service in purifying the atmosphere, and, as already mentioned, play an important part in ventilation.

The velocity of the wind is measured by an 'anemometer.' There are various forms of anemometer; some measure the pressure, others the velocity of the wind. One of the best instruments for measuring velocity is Robinson's, consisting of four arms, each provided with a hollow cup and rotating horizontally on a vertical axis, which, by means of an endless screw, causes movements to be recorded on a series of dials in terms of miles and parts of a mile. Winds may be divided into constant, periodical, and variable.

The *trade-winds* in the torrid zone blow throughout the year on each side of the equator, as a north-east wind on the north and as a south-east wind on the south, both winds being separated by a region of calms or variable weather (or of constant precipitation from the heavy rains). Harmattan is a local name of a north-east trade-wind which blows from the Sahara to the south of Cape Verd. It is, therefore, hot and full of sand.

Periodical Winds.—Among these are: The *Roaring Forties*, steady west winds of the North Atlantic, blowing often with much violence in winter.

Monsoons.—The term is used to describe winds whose direction shifts with the seasons, and which divide the year, however unequally, between them. They are found in the Indian and China Seas, etc. The monsoon introduces the rains in India.

In the Mediterranean there are a number of local wind-names:

Mistral, a cold, violent north-west wind affecting the Gulf of Lyons and West Italy.

Bora, the north wind of the Adriatic.

Gregale, north-east wind affecting Malta.

Levanter is a steady east wind along North Africa.

Sirocco (Spanish *Solanno*), an oppressively hot moist

wind from the Sahara, which blows in spring and autumn chiefly in Italy, Sicily, and Malta.

Föhn is the same wind somewhat cooled after crossing the Alps; it is the south-west wind of Davos Platz and other high Swiss health resorts; it leads to melting of the snow in spring, increases the humidity of the air, and is prejudicial to cases of chest disease deriving benefit from the high altitude.

Variable Winds.—These are due to local conditions; thus, by the sea-shore during the day the land gets more heated than the sea, hence there is an upper current from land to sea and a lower one from sea to land, the latter being known as the *sea-breeze*. After sunset the land cools more rapidly than the sea and the currents are reversed, the lower one being called the *land-breeze*.

Storms are described by Professor John Young as of two kinds: (1) Those due to acceleration of the prevailing winds by increased pressure behind, or by diminished pressure in front, as the sirocco tornado; (2) those in which the prevailing direction of the wind is changed, forming *rotatory* storms. They are of regular periodic occurrence in the Indian Ocean (as cyclones), at the West Indies (as hurricanes), and in the China Seas (as typhoons); in temperate regions they are as due to barometric changes.

Humidity.—This is expressed as relative or absolute.

The *relative humidity* of the air is the amount of moisture present expressed as a percentage of the amount necessary to cause saturation. Between 70 and 80 per cent. relative humidity is most agreeable in this climate. The wet and dry bulb thermometer is employed to determine this and the dew-point. If the two bulbs are of the same temperature, the air is saturated with vapour, and the temperature noted is the dew-point; the greater the difference between the two bulbs the lower is the relative humidity.

The moisture in the air is due to *evaporation*. This is influenced by temperature, wind, humidity, and rarefaction of the air, degree of exposure or shading, and by the nature of the moist surface. Thus evaporation is greater in spring than in autumn, greater from moist soil than from water; greater from sand or clay than from peat-

moss, the capillarity of earth being more than that of moss; vegetation retards surface evaporation, but gives off a large amount of moisture to the air, drawing up water from the deeper parts of the soil.

'No other factor singly exercises so profound, so far-reaching an influence on weather as the aqueous vapour of the atmosphere. Its liability to alter its form from the gaseous to the liquid or solid state and back again, the caloric phenomena which accompany these changes, and the extreme variability in amount of vapour present in the air—these all cause frequent fluctuations in temperature and pressure, in cloud and sunshine, in terrestrial and solar radiation, in wind and weather' (Moore).

By the *tension* or *elastic force* of aqueous vapour is implied the amount of barometric pressure due to the vapour in the air; it represents the *absolute humidity* of the atmosphere.

Condensation.—When the heat goes off the vapour is condensed as dew, rain, clouds, etc.

The *dew-point* is the temperature when the air is saturated with moisture, so that the least cooling causes a deposit of water. The dew-point may be calculated by means of a table of factors which have been worked out empirically by Glaisher. Take the difference between the wet and dry bulbs, multiply it by the factor which stands opposite the dry-bulb temperature in Glaisher's table, deduct the product from the dry-bulb temperature; the result is the dew-point (dew-point = dry bulb – (db – wb) factor of dry bulb). The pressure of the vapour in the air may be found by means of Glaisher's tables, and the *drying power* of the air can be found—that is, how much more vapour it could take up until saturated.

When *dew* is formed there must be a calm, clear sky, and a rapid depression of temperature. An object on the ground parts with its heat and cools the air in immediate contact with it; moisture is then deposited and prevents further radiation of heat. The dew-point thus determines the minimum temperature of the night. Anything which obstructs radiation, as the passage of clouds reflecting the heat, or the presence of currents of air equalizing the temperature, prevents the formation of dew. *Hoar-frost* results from freezing of the dew.

Fogs, Mist, etc.—When masses of warm, moist air come in contact with colder bodies, or become cooled on rising into the upper and colder parts of the atmosphere, fogs, mist, clouds or rain are produced. A necessary factor in the production of fog is the presence of dust, upon which the moisture may condense. According to Aitken, this is largely composed of particles of sodium chloride. Fog cannot be produced in dust-free air. The particles producing fog are so fine they scarcely fall through the air; a cloud is a little coarser in texture, while mist is coarser still; and rain is any of these while falling, whether it be a wetting mist or a drenching rain (Aitken). The fewer the particles of dust the heavier the drops become, as they collect more moisture in falling. The fogs which occur in large cities are consequent upon the artificial heat and smoke from fires, and the humidity derived from rivers whose colder air descends from surrounding hills. The globules adhere to particles of soot and sulphur, or are surrounded by a sooty envelope, hence the irritating effect when breathing. Such fog is the 'London fog,' which arrests the diffusion of carbonic acid, causing it to accumulate in streets and houses. Fog also checks loss of heat by radiation, which is beneficial in autumn by rendering the transition to winter more gradual.

Clouds are not a result of terrestrial radiation, but of a cooling process commencing in the upper regions of the air itself.

Dr. J. W. Moore suggests that the cirrus, the cirro-cumulus, and cirro-stratus forms of cloud which are found at a greater height than any other forms are usually composed, not of watery particles, but of minute ice crystals. The clouds which cap hills are usually fogs due to the cooling of moist air by contact with the cold hill-top.

Rain owes its origin to the cooling of saturated air. The periodic rains which follow the direction of great aerial currents (as the trade-winds) correspond to the passage of the sun across the equator. Variable rains are found in the temperate and polar regions: a rainy day is held to be one in which not less than 0·01 inch of rain falls in the twenty-four hours. At ordinary British stations falls of more than 2 inches in the twenty-four hours are not common.

Snow is due to the freezing of the aqueous vapours in the atmosphere; snow-flakes partially melted in their descent form sleet.

Hail formation is probably associated with alteration in the electric tension of the atmosphere. It occurs when the air near the ground is warm, but at a considerable height is intensely cold. Its formation is thought to be accompanied by a cyclonic whirl of the air in the vicinity of the storm-cloud, the axes being, however, almost horizontal instead of vertical, while the area is extremely limited.

Heat and Light.

The sun may be said to give out three kinds of rays—viz., heat, light, and chemical—the rays of light being the only ones visible. It is found that the greatest intensity of light lies towards the yellow part of the spectrum; beyond the red of the spectrum are the invisible heat rays, while beyond the violet are the chemical or actinic rays, also invisible. It is owing to the length of the waves that these are invisible; the length of light-waves diminishes from the red to the violet; the rays beyond the red have too long, and those beyond the violet too short a wave-length for the eye to see.

The colours produced in the atmosphere are due to the presence of vapour and dust, whereby rays of light undergo refraction and absorption. The phenomenon known as the 'mirage' is due to these causes, especially reflection; the layers of air in contact with the hot desert sands become more heated and less dense than those above them, so that rays of light falling obliquely upon these layers reflect distant objects, making them appear as if close by.

Twilight and dawn are due to similar causes. Twilight ends when the sun sinks to 18°, or at most 21°, below the horizon; sometimes there is a secondary reflection from the twilight, which is known as the *after-glow*.

Diathermancy designates the property possessed in various degrees by various substances of transmitting radiant heat. Diathermancy is to the dark heat-waves what *transparency* is to light-waves. Dry, pure air is perfect in both respects, but bodies which have equal

power of transmitting rays of light are very different in their power of transmitting heat-rays; thus glass, water, alum, and the majority of transparent substances do not allow dark heat-rays to pass, rock salt being an exception. Aqueous vapour absorbs a very large amount of dark heat while allowing light-rays to pass with scarcely any diminution (Tyndall); it thus allows the earth to be warmed, and prevents the heat being radiated back into space.

The *actinic* rays are powerful to excite chemical action, and probably it is their influence which renders sunlight a necessity for perfect nutrition and proper bodily development; to them also may be ascribed, in part at least, the benefits derived from 'sun-baths' by sufferers from rickets, etc. These rays have the power of decomposing chloride of silver, and are made use of in photography. Their presence may be demonstrated in another way; the phenomenon known as *fluorescence* has been explained by Professor Stokes to be due to the chemical rays being lowered from a condition of great to one of less refrangibility, so that when they fall upon a screen washed with a solution of sulphate of quinine they will be rendered visible as a blue lustre.

Exposure of the skin to violet and ultra-violet rays alone has been shown by Widmark to produce erythema, followed by desquamation; exposure, on the other hand, to red and ultra-red rays tends to exhaust the retina; photographers and photographic plate-makers having suffered severely from the effects of red light, use a canary-yellow or orange medium whenever practicable.

Atmospheric electricity varies in intensity periodically, increasing from June to January, and decreasing again to June; it varies also daily; experiments at Kew show that the mean electric state of the day is best represented about 11 a.m. Pure air offers little resistance to the passage of an electric current. It is accelerated by cold, retarded by heat. Its accumulation in the atmosphere depends upon the aqueous vapour present. If the formation of clouds is slow, equilibrium is quietly maintained, but if larger masses of vapour accumulate suddenly, and if these are in opposite (positive and negative) electric states, flashes of lightning pass between them, or between them and the earth, until equilibrium is estab-

lished. The flash consists of the various constituents of the air heated to incandescence. So-called forked lightning is due to the breaking up of the flash by unequal conductivity of different atmospheric layers. Sheet lightning is due to the reflection of distant thunderstorms.

The *aurora borealis*, or northern lights, is considered by Marret to be due to positive electricity from the sea between the tropics, being carried into the upper atmospheric regions and thence wafted to the poles, where it descends and meets the negative terrestrial electricity in a rarefied atmosphere.

It is only by the practical use of the various meteorological instruments that a proper knowledge of them can be gained. Scott's 'Instructions' will be found of service.

CHAPTER VIII.

FOOD.

Foods may be divided into two classes :

1. Nitrogenous.
2. Non-nitrogenous.

1. The **nitrogenous** consist of the *albuminoids*, or *proteids*.

(*a*) The *albuminoids* proper, having a composition similar to that of albumin. They are of both animal and vegetable origin, such as albumin blood-fibrin, muscle-fibrin, or syntonin ; myosin, globulin, casein, gluten, legumin, etc.

(*b*) The *gelatines*, as gelatin, ossein, chondrin, and keratin.

(*c*) The *extractives*, as kreatin, kreatinine, karnine, xanthine.

These are occupied with the formation and repair of all the tissues and fluids of the body ; they regulate the absorption and utilization of oxygen, and the transference of energy. They may, themselves, to a certain extent,

form fat, and thereby become oxidized. In the process of digestion they are converted into peptones. The members of group *a* are of similar composition, and may replace one another in nutrition; they have been called the 'digestible albuminoids.' The gelatines have a greater proportion of nitrogen in their composition, and are not of so great nutritive value.

The extractives act as regulators and stimulants to digestion, and are specially needful with the gelatines.

2. The **non-nitrogenous** include:

(*a*) *Fats* or *hydrocarbons*, consisting of carbon, hydrogen, and oxygen, the proportion of oxygen being less than sufficient to convert the hydrogen into water. Olein, stearin, margarin, butyrin, palmitin, are examples of this class. They supply energy and animal heat by their oxidation, and keep up the fatty tissues.

(*b*) *Carbohydrates*, containing the same elements as the fats, but with the hydrogen and oxygen in the same proportion as in water; such are starch, dextrin, cane, and grape-sugar, lactose, or milk-sugar. They act in a similar manner to the hydrocarbons, but the two groups are not entirely convertible; this group may, in part, be converted into fats by deoxidation.

Liebig divided the foods into flesh-formers (the proteids) and heat-producers (fats and carbohydrates), but later researches have proved that no such sharp line of demarcation exists, for not only can carbohydrates be transformed into fats, but may also contribute to the synthesis of proteids, and *vice versâ*. Sugar is found to greatly increase muscular energy and power of resistance to fatigue.

(*c*) *Vegetable acids*—tartaric, malic, citric, acetic, etc.—are frequently associated with the carbohydrates. These by conversion into carbonates preserve the alkalinity of the blood, and by their action on phosphates and chlorides contribute to the varied reactions of other fluids of the body; on oxidation they are capable of furnishing a small amount of energy and animal heat.

Salts, as chlorides of sodium and potassium, phosphates of magnesium, calcium, and potassium, iron, etc., exist in all tissues and fluids of the body, and are essential for the support of the bones, and for the regulation of energy and

nutrition; the growth of cells is dependent on the presence of phosphates, and digestion on the HCl derived from the chlorides; the soda salts exist chiefly in the fluids, the potash in the formed tissues.

Accessory foods, as tea, coffee, cocoa, and alcohol, have been termed with the salts 'force-regulators.' They give taste to food, excite the alimentary secretions, and stimulate the higher nerve centres.

Experience has proved to man the necessity of having representatives of all the four classes of foods—albuminoids, fats, carbohydrates and salts—in ordinary diet in certain relative proportions. The omission of one or other is followed by ill-health. This is not so marked when carbohydrates only are absent; excess of fats or of carbohydrates lessens oxidation of the other two classes, and hinders the metamorphosis of both fat and albuminoid tissues; excess of albuminoids causes more rapid oxidation at first, but if the excess be continued the food does not digest, but undergoes fermentative changes, producing dyspepsia, diarrhœa, flatulence, etc. It is probable that ptomaines are formed and absorbed into the system. Absence of those vegetable acids which form carbonates in the system produces the condition known as scurvy.

The relative amounts of these foods which should enter into a proper dietary scale have been calculated by various observers.

For a man of average size and weight (150 lb.), doing ordinary work, the following amounts (in round numbers, to facilitate calculations) may be taken:

Albuminoids ...	... 4·50	ounces.
Fats	... 3·00	"
Carbohydrates ...	... 14·25	"
Salts	... 1·00	"

Water.—Theoretically, each of the above is absolutely water-free, but practically, ordinary food contains between 50 and 60 per cent. of water, the weight of which has to be added to the above, so that the usual average range would be from 40 to 60 ounces of so-called solid food. As 50 to 80 ounces of water are taken in some liquid form in addition to that contained in solids, the total amount

of water is stated by De Chaumont to be from 70 to 90 ounces, or 0·5 ounce for each pound weight of body.

These amounts must be interpreted as representing minimum requirements. If men are undergoing great exertion they take more food, and in practice to get work done it is necessary to allow liberally for waste and non-assimilation, and to give a diet largely in excess of theoretical requirements.

De Chaumont estimates the internal work of the body to be equivalent to 2,800 foot-tons daily; and, according to him, to get an ordinary day's work done, say 300 foot-tons, we require five times that amount of energy (1,500), in addition to the quantity needed for the body's internal work, or $1,500 + 2,800 = 4,300$ foot-tons, to be provided from the material taken in as food.

The following scale gives the ultimate composition of various food-stuffs:

Substance.	Water.	Nitrogen.	Carbon.	Salts.
Uncooked beef ...	328	12	60	7
Cooked beef ...	236	19	110	13
Bread	175	5	120	6
Oatmeal	66	8·8	168	13
Potatoes ...	324	1·4	45	4
Butter	26	2	30	12
Milk (sp. gr. 1·029 and over) ...	380	2·8	30	3

From the analysis, by stating an algebraic problem, it is possible to determine how much of each ingredient in a dietary scale should be allowed to give the proper proportions of nitrogen, carbon, etc.

The proportion of nitrogenous substances to fats, carbohydrates and salts in standard diets is practically as follows: Proteids, 100; fats, 65; carbohydrates, 315; and salts, 23.

In terms of nitrogen and carbon the daily need of an average adult weighing 150 pounds, doing average work (300 foot-tons), may be stated as 307 grains (20 grammes) of nitrogen, and 4,700 grains (305 grammes) of carbon, the relation of nitrogen to carbon being as 1 to 15.

Assuming the water-free food requisite for a man of

that weight to be 23 ounces, each pound weight of the body receives in twenty-four hours 0·15 ounce, or the whole body receives nearly $\frac{1}{100}$ part of its own weight.

Another way is to calculate out the dry albuminoids, fat, and carbohydrates in ounces, and make use of the following figures :

Albuminoid 1 oz. contains	70 grs. nitrogen,	212 grs. carbon.
Fat	„	„	„	336 „
Carbohydrates	„	„	„	175 to 190 „

An allowance of 30 grains of carbon has been deducted from the albuminoids, as this amount is converted into urea, and is therefore not capable of being fully oxidized.

Almost every article contains some portion (5 to 10 per cent.) which cannot be utilized on account of its indigestibility ; much, however, depends upon the variety of food employed and the way in which it is prepared, in order that the nearest approach may be made to obtaining the theoretical value therefrom.

Meat.

Theoretically, it is immaterial whether the nitrogen in food is derived from animal or vegetable sources, but long use has rendered one form more acceptable and more easily digested than the other. Animal food contains a large amount of nitrogen, much fat and important salts, but no starch ; it is easily cooked, and appears to be more quickly assimilated than any vegetable ; change of tissue takes place more quickly in meat-eaters, so that they require more frequent supplies of food than vegetarians. Animal fats are more easily absorbed than vegetable ones.

Inspection of Dead Meat.—It is desirable that all abattoirs should be public rather than private, so that all the animals killed in the town may be passed through them and properly inspected ; private slaughter-houses are usually near the butchers' shops, and are therefore generally in central and crowded parts of the town. There are a number of ways in which dishonest traders often attempt to pass inferior meat on the market, such as :

1. Meat of animals which have died from disease, or from an accident, as by drowning.

2. Meat of animals killed and bled when there is no hope of recovery from illness.

3. Meat of animals which have been the subject of infectious disease, as foot-and-mouth disease, anthrax, etc.

4. Meat of tuberculous cattle, the lungs and pleura being removed.

5. Meat containing encysted parasites.

6. Meat beginning to decompose.

7. Horseflesh to be sold as beef; young goats for lamb.

If the animal be seen alive, it should, *if healthy*, present a well-nourished appearance; the coat should be soft, supple, and glossy, the eye bright and clear; the flesh should feel firm and elastic; the mucous membrane of the nose should be red, moist and clean; the tongue should be moist, warm, clean, and not protruding; the breath should have little odour, and the respiration be quiet and regular; the udder should be cool; the dung should appear natural; the reverse of these conditions indicates disease.

After death the viscera should, if possible, be secured for examination by naked eye and microscopically, the liver for abscesses or entozoa, the brain for hydatids, the lungs and pleura for tubercle, evidence of abscesses or strongylus filaria, the ribs for pleuritic adhesions, the omentum, peritoneum, and diaphragm in pigs for trichinæ. In German abattoirs routine search for trichinæ is conducted by systematic microscopic examination of the oculo-motor muscles. If tuberculosis be suspected and the carcass has been 'dressed,' the marrow may be examined for bacilli.

Good meat should have the following characteristics:

The *bone* should be about 20 per cent. of the whole.

The *fat* should be in proper proportion, firm, healthy-looking, and free from hæmorrhagic points; beef-fat is yellow, mutton white. The fat is much influenced by the nature of the food; thus, oil-cakes produce a deep yellow colour, and flesh-fed pigs have a soft, diffluent fat.

The *flesh* should be firm and elastic, with a marbled appearance; the surface should not be too moist; there should be no lividity on cutting across any of the muscles, and no softening, mucilaginous fluid or pus in the inter-muscular cellular tissue. Any juice exuding from the

meat should be small in quantity, of a reddish tint, neutral in reaction immediately after death, but becoming acid in about four hours. Good meat should dry on the surface after standing a day or two. The colour varies with age: it should neither be too pale nor too dark; if pale and moist, it indicates that the animal was young or diseased; if dark and livid, in all probability the animal was not slaughtered, but died with the blood in it. The odour of meat is important: beef has a special, insipid, but not unpleasant kind of smell; veal smells of milk, mutton of wool; pork has little smell, unless flesh-fed, when it emits an offensive odour. Commencing putrefaction is detected chiefly by the colour, loss of elasticity; later, by the change in odour. Diseased meat has often a disagreeable odour; this is especially noticeable underneath the shoulder and in the muscles of the internal crural region. An incision may be made, or a clean knife pushed in will, on withdrawal, convey any particular odour; if in the latter place, it may be possible to detect the smell of physic (aloes, etc.); the odour will also be given off if meat be chopped up and drenched with warm water. The resistance offered to the entrance of a knife gives another test in good meat—it is uniform, while putrefying parts of the meat are softer than others.

The *marrow* should be light, rosy red, and solid for twenty-four hours after killing; if soft, brownish, or with black points, the animal has been sick, or putrefaction has begun.

An animal that has died with the blood in it was presumably diseased, and it is customary to condemn such a carcass.

Frozen meat is apt to have the fat somewhat bloodstained. If improperly stored or thawed, the surface may be mouldy or tainted, the rest of the meat being good, but examination should always be made of the meat round bones. Animals which have recently given birth to their young and newly-born or prematurely born animals should not be used for food.

Horse-flesh is much coarser than beef and of darker colour. Penalties are imposed for selling flesh of horses, mules, or asses when some other meat has been asked for; and a large notice must be placed in a conspicuous

position indicating that horse-flesh is sold there (the Horse-flesh Act, 1889). The flesh of horses suffering from glanders or farcy would be unfit for food.

Diseases produced by Altered Quality of Meat.— Poisonous symptoms sometimes ensue after eating apparently sound cooked meat, especially when it has been allowed to get cold before being consumed. This is explained by the fact that microbes produce ferments which are not affected by cooking; these ferments are not themselves poisonous, but if allowed time to act on the albumin of the meat, will produce certain toxic alkaloidal bodies (see Chapter VIII., on Communicable Diseases). Various kinds of fish have also produced similar effects, as well as causing dyspepsia and urticaria.

The poisonous symptoms are of two kinds: one with violent gastro-intestinal irritation, cramps, and cardiac failure, as in muscarine poisoning; the other of an ataxic nature, accompanied by great depression, diminished mucous secretions, quickened pulse, paralysis of the muscles of the eyeball, etc.

B. Botulinus

A specific bacillus was discovered in samples of meat giving rise to outbreaks of poisoning on a large scale at Welbeck, 1880, and Nottingham, 1881, which were investigated by Klein and Ballard. Cultivations of the bacillus administered by inoculation or injection to rabbits, guinea-pigs, etc., caused death, with pneumonia and other symptoms. .Specific microbes have also been isolated from meat which gave rise to infectious pneumonia at Middlesbrough, and a bacillus, differing from the Welbeck bacillus, has been isolated from pork which gave rise to an outbreak of diarrhœa at Carlisle, 1889. Meat, however, from diseased animals may, as a rule, be eaten with impunity if thoroughly well cooked. It is when cooking has not been complete that danger occurs; and this is always liable to happen; it is therefore desirable to prevent the flesh of animals that have had communicable diseases being used for food. The following are the principal:

Tuberculosis.

Epidemic pleuro-pneumonia.

Anthrax, malignant pustule, charbon, black-quarter or splenic fever.

Splenic apoplexy, braxy of sheep.
Sheep-pox.
Foot-and-mouth disease, aphtha or eczema epizooticum.
Cattle-plague, rinderpest, typhus contagiosus.
Scarlet fever.
Pig-typhus, hog cholera, swine fever, or 'red soldier,' a specific pneumo-enteritis.
Glanders and farcy.
Actinomycosis.
Entozoa-cysticerci, trichinæ, echinococci, etc.
Fever following parturition.
Pyæmia, septicæmia.
Uræmia, jaundice.
Gangrene (as of the navel in calves).
Rabies (or flesh of an animal recently bitten by one rabid).
Various marked cachectic conditions—when marked physical changes have taken place as a result of inflammatory or febrile affections, or important forms of blood deterioration.

Sometimes poisoning is caused by the presence in the flesh of drugs, such as antimony and arsenic, when they have been given to the animal in large quantities, or if the animal has been poisoned accidentally by poisonous herbs or drugs.

Powers to prevent the sale of certain articles *intended for the food of man* are given in the Public Health Act, 1875, Sections 116-119. See also Public Health Act, Sections 166-170, and the Model Bye-laws, with reference to the establishment of markets and slaughter-houses, and on offensive trades, many of which are connected with the utilization of the refuse from slaughter-houses.

Slaughter-houses.—The Local Government Board require:

That they be not situated within 100 feet of any dwelling-house, and be so placed as to admit external air on two sides at least.

That the lairs or pens for cattle be independent of the slaughter-house, be properly drained, be at a distance from dwellings, and be just sufficient to hold those cattle about to be killed.

No rooms to be built over the slaughter-house.

No water-closet, privy, or cesspool to be in the slaughter

house, and no direct communication should exist with such or any stable.

Ample cross ventilation and proper lighting must be provided.

Floor to be concrete or asphalt, with slope to groove running to a trapped gully outside, whose bars should not be more than $\frac{3}{8}$ inch apart.

Walls to be coated with hard, impervious cement or glazed tiles to the height of 7 feet; above that to be lime-washed, with the ceiling, at least four times a year.

Water-supply must be sufficient, and there must be provided a galvanized tank at least 6 feet above the floor, and quite independent of it, to contain pure water.

Galvanized iron buckets to be provided, and all blood, offal, and garbage removed within twenty-four hours.

The slaughter-house must be thoroughly washed and cleansed within three hours after slaughtering.

In public abattoirs (or groups of slaughter-houses, from the French word *abattre*, to fell) good artificial light should be supplied, as much killing is done at night. There should be a separate department for suspected or condemned cattle.

Poultry.

Dr. Vacher says: 'Good poultry should be firm to the touch, pink or yellowish in colour, fairly plump, and should have a strong skin. It has a fresh, not disagreeable smell. Stale poultry loses its firmness, becomes bluish in colour, green over the crop and abdomen, the skin readily breaks, and the bird has a disagreeable odour. Chicken-cholera and tuberculosis render the flesh of fowls unfit for food. Tubercular nodules may be found in the liver and intestines.

Eggs.—An average egg weighs about 2 ounces avoirdupois; ten parts are shell, sixty white, and thirty yolk; 22·8 per cent. of egg is albumin and fat, 67·2 per cent. is water; hence a 2-ounce egg contains about 200 grains of solids.

The freshness of eggs may be tested thus: Fresh eggs on the light of a candle being allowed to shine through them, are seen to be most transparent in the centre, old ones at the top. Eggs laid by 'roupy' hens are not wholesome.

Fish.

When fresh, fish are firm and stiff, the eyes bright, the gills clean (not dry or exuding dirty brown fluid), the scales bright and unbruised. When unfit for food, fish become limp or soften in parts. Fish should only be eaten when 'in season.' This is regulated by the time of spawning.

Poisoning has been caused by apparently sound fish, especially herrings, probably from causes analogous to those noted in the case of the Ballard and Middlesbrough meat epidemics.

Shell-fish, especially mussels, may cause urticaria or even death from the development in their livers, when past the maximum stage of their growth, of mytilo-toxin which gives rise to intense intestinal congestion in the human subject.

Mussels, oysters, etc., when growing in water contaminated by sewage, may be the vehicles of enteric fever or cholera. The *Bacillus typhosus* has been proved to be capable of multiplying in the body of the mussel. Certain fish act as intermediaries in conveying the *Bothriocephalus latus* to mankind. Salmon suffer from a fungus disease which renders them unfit for food.

Tinned fish may have any of the above-mentioned defects, or may decompose owing to imperfect 'canning.'

Attempts are sometimes made to disguise defects in fish by smoking or curing them.

Milk.

Milk is a typical food, containing all the four classes of aliment essential to health, and is especially suited to provide the nourishment necessary during the earlier years of life, when growth is active.

From 20 to 25 pints in twenty-four hours is a good yearly average yield for a cow, but the quantity given, with the specific gravity and composition, varies according to the food and shelter of the cattle, the intervals between milking, the age of the calf, number of pregnancies, breed, age, and individuality.

Cow's milk, as compared with other milks, presents

certain differences which have an important bearing upon the feeding of infants and invalids.

It contains more casein, fat, and salts than human milk, but from 1·5 to 2 per cent. less milk-sugar.

When taken into the stomach it forms a firm clot, much less easy to digest than the loose flocculent ones resulting from human milk, or from that of asses, mares or goats, into which the gastric juices can easily penetrate.

Ass's milk is much poorer in solids, and goat's is richer than cow's milk.

Examination of milk.—The average composition by weight of cow's milk is as follows

Water	87·17	per cent.
Proteids, chiefly casein ...	3·55	"
Carbohydrates	4·88	"
Fats	3·69	"
Salts	0·71	"
Total solids	12·83	"

When placed in a tall glass it should be opaque, white in colour, without peculiar smell or taste, and without deposit.

Reaction should be neutral, or faintly acid or alkaline.

Specific gravity varies from 10·29 to 10·34; at 60° F. good milk averages 10·30. The specific gravity of the whey should be taken when possible; it is generally about 10·28.

The *total solids* are obtained by evaporation. They should be about 13 per cent., of which 3½ to 4 per cent. is represented by fat; but very inferior samples may contain much less. There is no legal standard, and various minimum limits are in use; the limit of 3 for fat and 8·5 for solids-not-fat laid down by the Society of Public Analysts, is usually accepted as a minimum. The fat may be extracted from the milk with ether by various processes, or in a centrifugalizer after treatment with strong acid to break up the proteids.

Microscopically fat is seen to exist in minute globules of various sizes, surrounded by an envelope of casein, and being lighter than the fluid in which they float, they tend to rise to the surface to form cream. Three per cent. of cream

is equivalent to about 1 per cent. of fat, so that good milk should yield from 12 to 15 per cent.; but by the ordinary method of taking off the cream, about a third of the fat is left behind; by using the centrifugal cream-separator nearly nine-tenths may be removed.

'The comparison of the specific gravity, and the amount of cream which rises with the physical characters, will give a very good idea of the quality of milk' (Parkes).

Adulterations.—The chief of these are water and annatto.

Water.—The addition of water simulates to a great extent the condition of very poor milk; it is detected by the lowered specific gravity, and by the diminished amount of total solids, or of the ash (0·73 per cent.); the various constituents are in normal proportions to one another. Creaming alone gives a higher specific gravity. The cream, of course, is less; but other constituents will be in normal amount. With creaming and watering combined the specific gravity may be normal, but cream will be deficient; quantitatively all the constituents will be deficient, but especially fat.

Annatto or *turmeric* is not unfrequently added to watered milk to make it look richer. An emulsion of annatto and borax has been found at the bottom of the glass in which the sample of milk was standing. To detect annatto in a sample of milk, dissolve in it some bicarbonate of soda, and partly immerse in it a piece of unsized paper; after a few hours the paper will be tinted orange. Methyl-orange is sometimes added to colour milk. This may be detected by mixing the sample with ammonia, and inserting a piece of clean undyed wool; the wool will become stained by the dye.

Glycerine.—Milk is sweeter than usual, and solids will not dry on evaporation.

Salicylic acid, boro-glyceride, boracic acid, and other preventers of fermentation are sometimes to be found in milk which has been sent long distances, etc.

Chalk and sodium carbonate are added to neutralize acidity produced by lactic fermentation. The chalk will deposit at bottom of glass, but the sodium carbonate can only be found by the effervescing of the ash, unless

sufficient has been added to give the milk an alkaline reaction.

Cream is sometimes adulterated, and even made with magnesium carbonate, tragacanth and arrowroot, etc. The microscope will detect the additions.

Preserved milk is prepared by sterilizing and bottling *in vacuo*, or by evaporating off some of the water and then sealing in air-tight tins or bottles, sugar being generally added. Brands of what is really condensed separated milk sweetened, and in some cases thickened with flour, are too often sold as 'condensed milk'; containing as they do only an infinitesimal amount of fat, these are highly injurious when used as the sole food of infants. A diet of this kind may fatten a baby, but tends to engender rickets and scurvy rickets.

Diseases connected with Milk.—Milk has the power of absorbing gases and vapours to a great extent, and if these are offensive or noxious they will produce their effects on the body. It also very readily passes through the lactic and butyric fermentation to putrefaction.

Stomatitis, gastric and intestinal irritation, etc., are produced by milk containing lactic acid, or fungi, as oïdium lactis, penicillium, aspergillus, etc.; or pus, etc., from an inflamed or suppurating udder. These are visible under the microscope.

The germs of tuberculosis, enteric fever, scarlatina, diphtheria, anthrax, and foot-and-mouth disease, whether introduced directly from the cow, from the hands of the milkers, from the water used to wash the milk-cans or to dilute the milk, or absorbed from the air—find in milk a suitable culture medium in which they multiply and by which they are conveyed. The occurrence of 'bovine scarlet fever' and also 'bovine diphtheria' may now be regarded as fully established.

Milk which has been kept for some time may develop a ptomaine called tyrotoxine, or cheese poison; it has been detected in ice-creams, which have proved to be poisonous.

The Regulation of Dairies, Cowsheds, and Milk-shops.—Under the Contagious Diseases (Animals) Act, 1886, England and Scotland, the Privy Council's Order of 1885 was adopted and amended by the Local Govern-

ment Board ; it requires that cowsheds, dairies, and milkshops must be properly ventilated and lighted, and have proper arrangements for water-supply, cleansing, and draining.

No person suffering from infectious disease, or in a condition to communicate infection, may take any part whatever in the production, distribution, or storage of milk, or handle any milk-vessels.

It is unlawful to occupy as such any milkshop or dairy having within it, or in direct communication, any water-closet, privy, or cesspool, after the expiration of a month's notice from the local authority.

No milkshop or milkstore may be used as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the place, and of the milk-vessels and milk therein.

Local authorities may frame regulations for inspection of cattle, for securing cleanliness of milkshops and milk-vessels, and for prevention of infection.

Milk from a diseased cow must not be mixed with other milk, or sold or used for human food ; unless first boiled it must not be used for food for animals. The word 'disease' is defined in the Act as meaning cattle-plague, contagious pleuro-pneumonia, foot-and-mouth disease, sheep-pox, or sheep-scab. In Ireland the Dairies Order of 1879 applies under the same Act.

See also the Infectious Diseases (Prevention) Act, 1890.

Butter.

When cream is churned the envelope of casein is broken, and the particles of fat coalesce.

The fat amounts to from 86 to 92 per cent. of the butter, and consists chiefly (88 per cent.) of stearic, palmitic and oleic (non-volatile, insoluble) acids, with butyric, caproic, caprylic and capric (volatile, soluble) acids 6·7 per cent., and glycerine. Butter also contains a little casein and a varying quantity of water ; salt should not be more than 2 per cent. in fresh, and 4 or 5 per cent. in salt butter.

Butter if properly made need not contain more than 12 per cent. of water. Any amount over 16 per cent. is probably due to admixture.

Adulterations.—Water, milk, annatto, and various starches are sometimes added, but the chief adulterants are other fats, chiefly animal. The term 'oleo-margarine' was applied to the imitation butter made from beef-fat; when churned up with milk and coloured it was termed butterine, but the Act of 1887 provides that 'all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not, shall be included in the term *margarine*, and no such substance shall be lawfully sold except under the name of margarine.' The best quality of margarine is made from a mixture of oleo-margarine, from beef-fat, nut-oil, butter-milk, salt butter, salt, annatto, and water. If the ingredients used in its manufacture are of good quality, margarine is no doubt wholesome and nutritious.

The method used to distinguish between true butter and its imitations depends upon the fatty acids they contain; if a sample is found to have more than 88 per cent. of the non-volatile fatty acids, it is adulterated. The melting and solidifying points of the various fats are also used as tests.

It is probable that butter may sometimes contain tyrotoxine.

Cheese.

The composition of cheese varies according to whether it is made from whole-milk (as Cheddar), skimmed milk (as Gruyère), or whole-milk with added cream (as Stilton), and also according to the method of manufacture; thus, cheese may contain from 20 to 30 per cent. of albuminoids, 12 to 38 per cent. of fats, 2 to 5 per cent. of salts, and 20 to 40 per cent. of water.

As with butter, so the chief adulterant or imitation is what is known as 'margarine, or filled cheese.' It is not included in the Margarine Act, and has not yet been brought into much public notice, although its sale is believed to be extensive. It is made from skim-milk and beef-fat, with colouring matter. Unless eaten new, it is said to become hard and indigestible.

To destroy insects, or give a colour to the rind, various metallic salts (copper, arsenic, mercury, lead) are sometimes applied.

Tyrotoxine, lactic acid, and various kinds of moulds may form in decaying cheese.

Diphtheria bacilli have been found in cheese, having been introduced into the milk.

Lard.

Pig's fat, freed from connective tissue and rendered at 120° F., constitutes lard ; properly manufactured it should contain no water, or only the merest trace ; the incorporation of even a very small quantity, as little as one-half per cent., is a source of considerable profit to the manufacturer.

A mixture of lard, with water, beef-fat, cotton-seed oil, and stearine, is manufactured and sold under the names of lardine, refined lard, and compound lard.

Stearine is frequently added to lard to give it firmness.

Vegetable Foods.

Wheat-flour, made from the whole grain, contains : water, 15 per cent. ; gluten (vegetable albumin), 8 to 10 per cent. ; soluble albumin, 1 to 2 per cent. ; starch, sugar, and dextrine, 60 to 70 per cent. ; fat, 2 per cent. ; potash and magnesia phosphates, etc., 1·7 per cent.

If the bran is removed before grinding, the flour is deprived of a large quantity of nitrogen, fat, and salts ; when it is allowed to remain it should be ground very fine, else its hard, siliceous nature may irritate the bowels.

Cooking renders starchy foods more digestible by rupturing the cellulose surrounding the starch granules, to which the saliva and pancreatic juice can then obtain access ; the albumin is coagulated and some of the starch is turned into dextrine.

Wheat-flour may be adulterated with other flours, or with potato or rice starch.

Flour which has been exposed to damp in transit or during storage rapidly deteriorates and becomes a nidus for the growth of organisms animal and vegetable, weevils, moulds, etc.

Cereals, especially rye, are liable to be attacked by ergot, the mycelium of *Claviceps purpurea*. This parasite is apt to produce symptoms of ergotism, viz.—stasis leading on to gangrene of the extremities. Its presence in flour

can be detected by an odour like that of herring brine developed on the addition of potash.

Bread is formed by the minute division of the dough by carbon dioxide. This may be produced by the use of yeast, of baking powders, or by forcing CO_2 through by pressure (aerated bread). For this last kind of bread the following advantages are claimed: that it contains no yeast, which might produce fermentation in the stomach, or might be impure; that no starch is lost; and that whiter bread is produced. But it may not be so digestible as bread made with yeast.

Adulteration of bread.—Very little now exists, but in poor districts damaged or inferior flour is not unfrequently used. Bread made from such flour will be dark in colour, of acid taste, and unpleasant smell, and may give rise to gastric and intestinal troubles. *Lolium temulentum*, or bearded darnel, may sometimes get into flour by accident; it gives rise to narcotic symptoms.

Alum is illegally added in the making of bread in order to arrest excessive fermentation and prevent the formation of lactic and butyric acids, to whiten the bread, to enable inferior flour to be utilized. It lessens the nutritive character of the bread by joining with the phosphoric acid and rendering it insoluble. As unalumed bread may contain from $1\frac{1}{2}$ to $2\frac{1}{2}$ grains of phosphate of alumina per pound, it is necessary to make a quantitative analysis before adulteration can be detected with certainty. Decoction of logwood is sometimes used to test roughly; slips of gelatine are soaked in an aqueous solution of the suspected bread; if the bread is pure, the gelatine is stained only reddish-brown by logwood, and can be decolourized by glycerine; alumed bread gives a blue colour permanent in glycerine (Winter Blyth). If the bread is sour this test may be fallacious.

Or, to a clear aqueous solution of the suspected bread, add a few drops HCl and barium chloride; a slight precipitate will probably be due to sulphate of potash or magnesia in the water, or salt used in the baking, or to a slight amount of H_2SO_4 naturally existing in the grain or added during the grinding; a large precipitate indicates the probable presence of alum, but it is not certain (Wanklyn).

Lead sometimes obtains admission to the flour in the process of grinding, as holes in millstones are often filled with combinations of lead, red-lead, borax, and alum.

Special regulations for the proper construction and management of bakehouses are laid down in the Factory and Workshop Act, 1901, and the Public Health (London) Act, 1891.

A comparison between wheat and other vegetable foodstuffs may be made from the following analytical table by De Chaumont, Letheby, and others; the leguminosæ are remarkable for the large quantity of nitrogen they contain in the shape of legumin or vegetable casein combined with sulphur and phosphorus, but they are somewhat indigestible.

Articles.	In 100 Parts.				
	Water.	Albuminates.	Fats.	Carbohydrates.	Salts.
Wheat-flour ..	15	11	2	70·3	1·7
Barley-meal ..	11·3	12·7	2	71	3
Oatmeal ..	15	12·6	5·6	63	3
Rye	13·5	13·1	2	69·3	2·1
Maize ..	13·5	10	6·7	64·5	1·4
Rice	10	5	0·8	83·2	0·5
Arrowroot ..	15·4	0·8	—	83·3	0·27
Peas (dry) ..	15	22	2	53	2·4
Potatoes ..	74	2	0·16	21	1
Cabbage ..	91	1·8	0·5	5·8	0·7
Meat (average)	74·7	17·7	6	—	1·6

The ready recognition under the microscope of the various starches can only be obtained by a careful comparison of their characters. Of the *unfacetted* starches, that of potato should be compared with those of the arrowroots and with pea-starch; wheat-starch with those of barley and rye. Of the *facetted* starches, sago, tapioca, and Rio arrowroot with one another, and with unfacetted arrowroots; oats with maize and rice.

The microscopical appearances of plants affected by mildew fungi, or by insects, should be known. Of the fungi, smut (*Ustilago segetum*), bunt (*Uredo fœtida*), or red rust (*Puccinia graminis*), affecting the stem and leaf of wheat, ergot of rye (*Oidium abortifaciens*), *Peronospara infestans* of potato disease are the commonest; and of insects the weevil (*Calendra granaria*), the *Vibrio tritici*, and the *Acarus farinæ* may be mentioned.*

Beverages.

Alcohol with CO_2 is yielded by the fermentation of the glucoses, cane-sugar passing into grape-sugar before the production of alcohol commences. This ethylic alcohol (C_2H_6O) is contained in spirits, wines, and beer in varying proportions, and is not unfrequently accompanied by traces of other alcohols (propyl, butol, and amyl) simultaneously produced; the chief of these is amylic alcohol ($C_5H_{12}O$); it is a constant accompaniment when sugar is used which has been derived from starch. It forms the chief ingredient of 'potato-spirit,' or 'fusel-oil,' and is frequently used to adulterate or to imitate whisky, brandy, and rum.

Wine contains from 6 to 25 per cent. of anhydrous alcohol (over 13 per cent., however, is not produced by fermentation, and must have been added to the wine); a number of ethers, on which depend the 'bouquet'; some albuminous substances and extractives; sugar and other carbohydrates are present in most wines, in some to a large amount; also abundant vegetable salts, which render wine of value as an anti-scorbutic. Wines are adulterated with water, distilled spirits, artificial colouring matters, as fuchsin, lime-salts, tannin, alum, lead, copper, logwood, catechu, cider, perry, etc.

Lead poisoning has happened as a result of the drinking of acid wines (especially home-made) which have taken up lead from the vessels in which they have been made.

Beer should contain from 2·8 to 10 per cent of alcohol.

* Messrs. W. Watson and Sons, 313, High Holborn, supply a box containing a series of microscopical slides specially arranged for public health students.

By 'pure beer' is understood a fermented infusion of malt flavoured with hops, but in practice glucose is generally used in the manufacture of beer in order to obtain a clear article. Sulphuric acid is employed in the manufacture of glucose, and a serious epidemic of arsenical poisoning, taking the form of peripheral neuritis, has recently (1901) occurred among beer-drinkers due to the use of impure sulphuric acid containing a large amount of arsenic from the ores used in its preparation.

Alum, common salt, quassia and other bitters, picric acid, and colouring matters are among the chief adulterations of beer. Water is sometimes added before retailing.

Spirits are for the most part (50 to 77 per cent.) flavoured alcohol, various ethers, and, sometimes, aromatics and essential oils. They do not contain the ingredients which give a dietetic value to wine and beer.

Proof spirit contains 56·8 per cent. in volumes of absolute alcohol, rectified spirit 84 per cent.; whisky, brandy, and rum may not be retailed of a strength weaker than 25 below proof, and gin 35 below proof, without notice being given to the purchaser.

The intemperate use of alcoholic beverages has a marked effect upon mortality, increasing diseases of the brain, circulatory and digestive systems. The mortality is greater in those intemperate on spirits than in those on beer.

Total Abstinence.—The evidence which of late years has been forthcoming from life assurance offices, friendly societies, Arctic explorers, African travellers, military commanders, etc., clearly shows that the practice of total abstinence from intoxicants is accompanied by greatly lessened rates of sickness and mortality.

Non-Alcoholic Beverages.

Tea and **coffee** depend for their restorative properties upon alkaloids (thein and caffein) of similar composition. They contain also much cellulose, tannin, and aromatic oils.

Coffee is adulterated with chicory, cereal grains, beans, potatoes, and sugar. Microscopical examination will

readily detect most of these. If a mixture of roasted coffee and chicory be thrown on water, the latter sinks at once, while the former floats for a long time. Chicory is itself adulterated with roasted barley, wheat, acorns, mangel-wurzel, sawdust, beans, peas, parsnips.

Tea is not now much adulterated.

Cocoa, besides containing theobroma (similar to caffein) has nearly half its bulk composed of fat, and from 13 to 18 per cent. of albuminoid substances. It differs from tea and coffee, therefore, in being not only a nerve stimulant but also a nourishing article of diet. As the quantity of fat is rather large, various methods are adopted with the intention of remedying this. The best of these is one whereby some of the fat is removed. There should be at least 20 per cent. of cocoa butter left (Society Public Analysts). Other less successful methods consist in the addition of cereal grains, starches, sugar, carbonate of potash, etc.

Aerated waters contain a variable small proportion of soda or potash, etc., and often consist merely of water with CO_2 pumped in under pressure.

Condiments.

Mustard is adulterated with turmeric (detected by microscope and liquor potassæ), wheat and barley, starch (microscope and iodine), and linseed (microscope) ; clay, plaster of Paris, and cayenne are sometimes added.

Pepper is adulterated with ground rice, sand, ground olive-stones, or 'poivrette,' wheat and pea flour, rape or linseed cake, cayenne and mustard husks, and the sweepings of pepper warehouses. These adulterations may be detected under the microscope. True pepper becomes intensely yellow when covered with strong HCl, so that foreign substances may be readily picked out.

Vinegar should contain from 3 to 5 per cent. of acid calculated as glacial acetic acid. The specific gravity of white wine vinegar varies from 1·015 to 1·022, malt vinegar from 1·016 to 1·019. If the specific gravity be low, and the acidity high, sulphuric acid has probably been added.

Pickles and preserved vegetables are sometimes coloured with copper, but its place is now taken to a great

extent by chlorophyll and other innocuous vegetable colouring matters.

Confectionery may be unwholesome from colouring matters introduced, or from the addition of insoluble substances, as paraffin wax in place of cocoa butter.

The Sale of Food and Drugs Acts, 1875 and 1879, give power for the analysis of every article used as food or drink by man except water; drug includes medicine for external or internal use.

In purchasing samples, sufficient must be obtained for subdivision into three parts, one to be kept by the vendor, one to be analyzed, and one to be kept for future comparison.

Exercise.

The regular action of the voluntary muscles, which is known as exercise, is necessary for the maintenance of good health. Without it the involuntary muscles, especially the heart and other organs, are much interfered with in the performance of their functions.

Effects of a proper amount of exercise: The oxidation of carbon is increased, chiefly in the muscles, and it is eliminated with an increased amount of watery vapour from the lungs. The circulation becomes more rapid, and greater pressure is produced on the vessels, hence there is a quicker removal of effete matters, and a more rapid renewal of tissue. Oxygen is necessary for muscular exertion, and, as its absorption is dependent on the amount and action of the nitrogenous structures of the body, more nitrogenous food is required with increased muscular work, else the growing muscles will rob other parts of the body (Pettenkofer and Voit's observations). For every additional foot-ton of visible work 1 grain of nitrogen should be added to the food.

It is believed that during periods of rest oxygen is stored up in the muscles, and it is from this source that the greatest amount is drawn during action.

Excessive or misdirected exercise may lead to pulmonary congestion and hæmoptysis; to cardiac rupture, palpitation, hypertrophy, and occasional valvular disease, injuries to bloodvessels, and to exhaustion of the muscular system; this latter is due to the accumulation in the muscles of

the products of their own action, especially paralactic acid, and to exhaustion of the supply of oxygen.

Deficient exercise favours spinal curvature, tubercular disease of the lungs, cardiac debility, dilatation and fatty degeneration ; lessens the appetite, enfeebles the digestive power, and produces congested conditions of the abdominal organs ; the nervous system becomes morbidly excitable ; it appears to lead in two or three generations to degenerate mental formation.

Amount of Exercise.—To enable comparisons to be made between different kinds of exercise the 'foot-ton' or 'foot-pound' has been adopted as a unit whereby to express the amount of work done. One hundred foot-tons means that 100 tons are lifted 1 foot in a certain time. Sometimes pounds are used instead of tons, and in France it is expressed as so many kilogrammes lifted 1 metre.

Three hundred foot-tons is an average day's work for a healthy, strong adult ; 400 foot-tons is a hard day's work. The internal work of the heart and muscles of respiration is equal to about 260 foot-tons, that for the heart varying from 122 to 277, and for respiration being about 11 foot-tons in twenty-four hours.

In calculating the work done by walking or climbing exercise, the following formula is employed :

$$\frac{(W + W_1) \times D}{20 \times 2{,}240} = \text{foot-tons}.$$

W is the weight of the person ; W_1 is the weight carried ; D is the distance walked in *feet;* 20 is the coefficient of traction, and is obtained from calculations showing that walking on a level surface at the rate of three miles an hour is equivalent to raising one-twentieth part of the weight of the body, etc., through the distance walked ; 2,240 is the number of pounds in a ton. To get the distance in feet, multiply 5,280 by the number of miles walked. Three miles an hour appears to be the rate at which the greatest amount of work can be done at the least expenditure of energy. Work becomes heavier and more exhausting if done in a shorter time—that is to say, velocity is gained at a disproportionately increased expense of the amount of work.

From a consideration of the effects of exercise on the body Parkes has deduced the following rules:

1. During exercise there must be no impediment to the freest play of the chest and respiratory muscles, else the removal of CO_2 will be checked. When breathing becomes laborious, with sighing, rest is necessary.

2. Food containing carbon and nitrogen must be increased with extra work. Carbon is best given in the form of fat.

3. Alcohol lessens the excretion of pulmonary CO_2, and deadens the action of the nerves of volition, and hence prevents great or continued exertion.

4. As excretion of CO_2 is increased, a large amount of pure air is required; in covered buildings ventilation must be carried out to the greatest possible extent.

5. In commencing unaccustomed exercise, the action of the heart must be closely watched; the chief object of special 'training' is to get a concordant action established between the heart and the bloodvessels.

6. The skin should be kept extremely clean; during exertion it may be thinly clothed, but immediately after, or in the intervals of exertion, it should be covered sufficiently well with flannels to prevent the least feeling of coolness of the surface. The evaporation from the skin is nearly doubled, and the temperature is kept normal thereby. Any interference with it causes languor; and as it continues after exertion ceases, there is great danger of chill if extra clothing is not applied. After active exercise a good bath is useful to remove sweat, chloride of sodium, fatty acids, etc., which accumulate on the skin.

7. Water is absolutely necessary during and after exercise; it is better to take small quantities frequently during exercise than a large amount afterwards, when it might be dangerous from its sudden cooling effect. The precaution may be taken of holding the cold water in the mouth for a short time before swallowing.

8. Exercise should be adapted to the physical constitution, and should develop the whole system, and not be confined to certain groups of muscles which after enlarging will, if over-exercised, commence to waste. The periods of life when extra exertion should be taken with caution

are between the ages of fifteen and seventeen, when the most rapid growth takes place, and later in life, when the arteries become atheromatous. The Swedish system (Ling's) of gymnastics is well fitted to properly develop all parts of the body; but, as already pointed out, exercise in a covered building, as in gymnasia, should never be allowed to supersede outdoor sports. Exercise should be systematic and regular, and never sudden and violent; it should not be taken directly after meals.

CHAPTER IX.

COMMUNICABLE DISEASES.

THE term '*zymotic*,' which is used to describe communicable diseases generally, in consequence of their course presenting more or less resemblance to a process of fermentation, is also employed in a limited sense to designate those diseases which occur in epidemics. The term '*specific*,' while undoubtedly a good one to describe many of these affections which arise from a specific cause, cannot, as yet, be held to be sufficiently accurate to include the whole class.

The Registrar-General, in his reports, now classifies most of the communicable diseases in six orders under the heading '*Specific*, *Febrile*, or *Zymotic Diseases*,' viz.:

1. Miasmatic diseases—Eruptive fevers, influenza, pertussis, epidemic pneumonia, bubonic plague, etc.
2. Diarrhœal—Enteric, simple, continued, cholera, dysentery, diarrhœa, etc.

These two orders include the diseases described by the Registrar-General as 'the seven principal diseases of the zymotic class.' They are: (1) Small-pox, (2) measles, (3) scarlet fever, (4) diphtheria, (5) whooping-cough, (6) diarrhœa, (7) fever — typhus, enteric, and simple continued (febricula).

3. Malarial diseases.
4. Zoögenous diseases include vaccinia, rabies, glanders, splenic fever.
5. Venereal diseases.
6. Septic diseases include erysipelas, pyæmia, septicæmia (puerperal and non-puerperal).

Tubercle in its many manifestations and leprosy, of both of which the bacilli are well-known, must now be included among the specific diseases.

All the above are now attributed to the action of *pathogenic* members of the class of micro-organisms known as *schizomycetes*, or fission-fungi—a class which contains also other organisms, many of them beneficent and useful in their action, as in the destruction of dead animal and vegetable matter. Although contained in a sheath of cellulose, they belong functionally to the animal kingdom rather than to the vegetable, as they are occupied in breaking down the higher and more complex bodies into simpler ones.

Other pathogenic organisms fall under the classes *saccharomyces* (*torulaceæ*, or yeast fungi), as the *oidium albicans* of thrush, *hyphomycetes* (mould fungi, or mycelial fungi); *e.g.*, actinomyces, or ray fungus—and protozoa—*e.g.*, *plasmodium malariæ*, the pathogenic organism of malaria, etc.

Bacteria are divided into several classes, according to their shape. Thus there are:

Cocci, round and oval; they increase by fission, but sometimes the separation is not complete, and a *diplococcus* is formed, as in pneumonia.

When cocci are arranged in the form of a chain the term *streptococcus* is employed.

Staphylococcus, so called from their tendency to occur in groups like grape bunches, is a group of cocci, of which an example is seen in the process of suppuration. When cocci occur in groups of four or more multiples thereof, the name *sarcina* is applied. Other subdivisions are formed by adding the name of the disease with which they may be connected, as *Streptococcus scarlatinæ*, or the name of a colour when colouring matter is formed during growth, as the *Staphylococcus pyogenes aureus*.

Bacilli are rod-shaped, and present various appearances. Some develop rapidly by fission, and appear in

their young condition like cocci; as with cocci, the bacilli may remain joined end to end after increase and then form chains, threads, or filaments—*Leptothrix* as *B. subtilis*, and *B. anthracis*.

Vibriones are curved or comma-shaped cylindrical bodies which, sometimes by simple elongation, sometimes by the junction end to end of comma-shaped elements, form spiral or corkscrew-like filaments or spirilla. This last must not be confounded with the spirillum, which belongs to the flagellate protozoa (Klein).

Bacilli multiply by fission, but many of them (the bacilli of enteric fever and diphtheria are exceptions) have also the power of producing seeds, or *spores*, in their interior under certain conditions; these are: the presence or absence of oxygen, proper temperature, and the presence of sufficient moisture. When the bacillus dies, the spores are set free. Spores (like other seeds) have greater power of vitality than the full-grown bacilli; hence it is more difficult to prevent the spread of diseases due to spore-bearing bacilli by disinfection than of diseases in which the microbes are non-spore-bearing. The vitality of many of the spores is so great that if circumstances favourable for immediate growth are not present they will survive for very long periods; outbreaks of diseases which seem spontaneous in their origin may be thus explained: thus, no coccus or bacillus can survive a temperature above 65° C. (149° F.), while some spores are not killed by being raised to boiling-point unless they are kept for some time at it. Dilute acids have little effect on them, and they even withstand drying, which is fatal to all other organisms. To render water absolutely sterile it is requisite to boil it three or four times at intervals of a few days, so as to kill off successive generations of bacteria that may have been hatched out from spores.

The term 'bacteria' was at one time used to describe the shorter rod-forms, but it now includes the whole of the schizomycetes.

In order to be able to state definitely that any disease is due to the action of a given microbe, it is necessary to fulfil certain conditions, as formulated by Koch:

1. The microbe must be found in the body of the man or animal suffering from or dead of the disease.

2. The microbe must be isolated and cultivated in suitable media outside the body of the animal. The cultivations should be carried on through successive generations of the organism in order to insure its purity.

3. A pure cultivation, when introduced into the body of a suitable healthy animal, must produce the disease in question.

4. In the inoculated animal the same microbe must again be found.

For some diseases—as anthrax, relapsing fever, erysipelas, pyæmia—it has been possible to fulfil these four conditions, but, owing to the difficulty of fulfilling the third of Koch's conditions, the connection between some other diseases and the microbes attributed to them has not yet been completely established.

The Cultivation of Microbes.—In the examination of air, water, and the fluids and tissues of the body, many kinds of microbes may be seen under the microscope, but it is possible to distinguish them from one another only by comparing their reactions to staining fluids and their appearance and mode of growth in certain media. The media which are used are both solid and fluid : potatoes, peptone-gelatine, agar-agar (Japan isinglass), bread-paste, chicken-broth, milk, blood serum, urine, various chemical solutions, most of which contain sugar and phosphates. Germs grow in nutrient jellies in a manner varying with the way in which they are planted ; the usual methods in tubes are surface, depth, and streak cultivations. Gelatine jelly is used when the required temperature at which the tubes have to be kept is under 25° C. (77° F.), at which point it liquefies ; agar-agar liquefies at 35° C. (95° F.). These media, as well as all apparatus with which either the microbes or the media come in contact, must be thoroughly sterilized, so that the cultivations which are made may be 'pure'—*i.e.*, unmixed with stray microbes.

It is found that some organisms grow better in one kind of soil, others in another ; thus pathogenic germs grow best in an alkaline medium, putrefactive in an acid one ; while many organisms can obtain nitrogen from simple bodies, as ammonia and air, pathogenic bacteria require very complex nitrogenous substances like albu-

min. It is not every acid, however, which interferes with the growth of pathogenic germs, as the acid surface of a potato affords a favourable nidus. Besides these points, their growth is influenced by temperature—some may thrive just above freezing-point and others not under 60° C.; but these extremes are rare, from 16° to 42° C. is the usual range—by the presence of mineral matter (amount and kind), and by the presence or absence of oxygen (aërobic or anërobic).

Some microbes can exist either with or without free access of air. Anthrax forms spores only when growing aërobically, while the microbe of tetanus if exposed to the air during growth produces no toxin, and is not pathogenic. The consumption of oxygen from the air is accompanied in some bacilli by active movement in the fluid in which they are growing; the motion, which may be of a serpentine description, as in enteric fever bacillus, or in a circle (as in hay infusion), or simply backwards and forwards, is due to the bacilli being provided with cilia or flagella. This movement is to be distinguished from the so-called Brownian molecular movement. When there is an insufficient supply of air in the fluid, the movements cease and the bacilli crowd to the surface, forming a pellicle.

Organisms have been divided into classes—*aërobic*, growing in air; *anaërobic*, those unable to grow in the presence of free oxygen. Each of these has again been divided into *obligate* (growing only when oxygen is present) and *facultative* aërobics (growing best when oxygen is present, but able to live without it). Anaërobics are similarly divided—thus, *obligate* or true anaërobics, which cannot grow where there is oxygen; *facultative*, which can live in the presence of oxygen, but grow best in its absence.

Experiments by Dr. A. McFadyen, as detailed by Dr. (now Sir) Lauder Brunton in the 1889 Croonian Lectures, show that those organisms connected with disease secrete a ferment or enzyme, which can be isolated, and which will continue to act after the microbes have been destroyed. He has also demonstrated that some bacteria can adapt themselves in a measure to the soil on which they grow, and produce such a ferment as will act upon the particular soil. It appears that a temperature which may destroy

the microbes themselves does not stop the activity of the ferment which they have formed. These ferments may produce toxic products resembling alkaloids, and not affected by heat. In this way may be explained those cases of poisoning which have happened after eating pies, hams, or other cold meats which have been cooked some little time before eating; but it is not unlikely that, as such cases occur but comparatively rarely, the dangerous poisons are produced by the action of more than one kind of bacteria. Sir Lauder Brunton suggests that this might happen when the dangerous meat is got from a diseased animal, the microbes already in its tissues combining their action with that of ordinary putrefactive bacilli.

These poisons are known as *Ptomaines* when formed by the decomposition of albumin by the microbes of putrefaction in the dead body; the more poisonous bases produced by pathogenic germs Brieger has named *Toxins*. These bodies have been found to produce, as in diphtheria, other poisonous bodies—one an organic acid, the other an 'albumose' (toxic albumoses exist in snake poison). Those bodies formed in the healthy living body by the breaking down of albuminous matter in the course of functional activity are called *Leucomaines*. 'Fatigue-fever' may be explained by the production of leucomaines being more rapid than the excretory organs of the body can keep up with; a similar explanation may also serve for uræmia. Other results of the action of soil microbes we have seen in the process of nitrification, and in the purification of rivers, etc. Some bacteria produce pigment, some phosphorescence, some offensive gases.

Microbes and Disease.—Microbes, in order to produce disease, must obtain admission for themselves or their products to the body; this is done in several ways: some (such as those of syphilis, glanders, rabies, and vaccinia) enter only by direct inoculation, others (saprophytic bacteria) can only enter when a tissue becomes dead or diseased; some (those of influenza and measles) are air-borne, and enter by the respiratory mucous membrane; others, again (such as those of cholera, dysentery, and diarrhœa), may enter with food or water as well as by the air, and act primarily on the gastro-intestinal tract; but it is not improbable that, under favourable conditions, all these

diseases might be produced by inoculation (Bristowe). It is not always, however, when bacteria obtain admission to the system that disease is produced. The explanation of this is to be found (1) in the insusceptibility of the body, and (2) in the degree of virulence of the microbe.

1. *Insusceptibility or Immunity may be Natural or Acquired.*—In regard to the former, white mice, *e.g.*, are not affected by diphtheria, rats by anthrax, or fowls by tetanus. An acquired insusceptibility is shown in persons convalescent from diphtheria, who may have virulent diphtheritic bacilli present in the naso-pharynx often for weeks, yet remain unaffected by them.

Several theories exist to explain these conditions, and probably more than one of these theories embodies a portion of the truth. Metchnikoff advanced the theory that certain white corpuscles of the blood have a phagocytic action; Behring claimed that the power to destroy micro-organisms and the toxins generated by them is inherent in the blood-serum; Hankin and others have shown the protective power of the living body to be due to the presence in the blood-serum of defensive proteids ('alexins' of Buchner), which may be produced by blood corpuscles or by other tissue cells; while their increasing power to produce these defensive proteids as the person grows older would explain the less susceptibility to infectious disease of the young as compared with adults. The introduction into the blood of a specific organism or of the poison produced by it stimulates the cells to produce a greater quantity of the protecting substance, which may be so modified by the particular microbe as to act also as a direct antidote to the poison evolved by it. This antitoxic blood-serum, if injected into another animal, will render it immune for a time; the immunity, however, of the first animal is fairly permanent, and a condition resembling natural immunity has thus been acquired.

2. *The Condition of the Microbe.*—Pasteur has demonstrated the fact that it is possible to increase, diminish, or altogether destroy the virulence of pathogenic organisms by causing modifications in their environment. Thus, the same bacterium may produce different results according as it is introduced into the blood or the subcutaneous tissues.

Again, in regard to swine plague, if the microbe is passed through a series of pigeons it becomes more virulent in its action, while, after passing through a series of rabbits, the converse is the case, and it is no longer able to kill pigs (Watson Cheyne). The relation of cow-pox to human variola is probably susceptible of a similar explanation. Exposure to the oxygen of the air also has the effect of mitigating the strength of the original virus. It has also been shown that the presence of one species of bacteria or its products may effect the growth of another species, increasing or decreasing its virulence.

Pasteur found that inoculation with attenuated virus would produce local mischief, with slight constitutional disturbance, which would, however, act as a preventive (for some time) against future attacks of the disease. Cattle have by this means been rendered insusceptible to splenic fever, even when inoculated subsequently with the germs of the disease in their most virulent form.

Pasteur has been able to apply this knowledge in the treatment of persons bitten by animals affected with rabies. The rationale of the method is as follows: The strength of the virus is increased by transmission through rabbits or guinea-pigs. The greater the potency, the shorter is the stage of incubation, which can be ultimately reduced to seven or eight days. This potent rabbit virus, as contained in the spinal cord, on exposure to a dry atmosphere, becomes gradually attenuated, but the shortness of the incubation period when it is inoculated is still maintained; hence Pasteur thinks that the seeming attenuation is due to the formation of some substance which tends to neutralize the poisonous properties. Inoculation with the mildest form before absolute inertness is reached has only a preventive influence against the effect of a virus a little less reduced than itself. As the normal incubative period of rabies in dogs and men extends over several weeks, time (ten days) is given to perform a series of inoculations gradually increasing in potency, each one of which will be protective against the succeeding one; the last and strongest will then be protective against that produced by the infliction of the bite.

Action of the Microbes in the Body.—As already mentioned, bacteria may enter the system and produce their effects therein, or they may remain, like tetanus and diphtheria, at the seat of inoculation, and send their poison only into the body ; or the organisms themselves may not be pathogenic, but their products may have toxic powers on absorption into the body, as in septic intoxication (sapræmia) and in meat-poisoning.

The terms *endogenic* and *ectogenic* were at one time employed to differentiate between microbes such as those of hydrophobia, small-pox or syphilis, which are only known to thrive in the animal body, and those that are capable of an independent or saprophytic existence, such as the microbes of cholera, tetanus, anthrax, etc. It now appears to be probable that most microbes are capable under appropriate conditions of saprophytic existence as spores or otherwise. When the microbes of any specific disease enter the system, the symptoms which follow are generally divided into stages ; thus, there is for a longer or shorter time a period of quiescence, latency, or incubation, during which it is supposed that the microbes are establishing themselves and generating their specific toxins. The smaller the number of microbes originally introduced, the longer may be the incubation stage and the milder the attack. If the dose be small or weak and the body in good condition, the disease may be checked and never get beyond the incubation stage, but usually there follows the period of *invasion*, which is characterized by increased temperature, rigors, etc. When the distinctive features of the disease appear, the stage of *advance* or *eruption* has begun ; these special features appear to be due to the fact that, after undergoing development in the invasion stage, the toxic products tend to attack particular organs, as the throat, bowels, nervous system, skin, etc. Ultimately, if the antitoxins formed overcome the bacteria, these perish, and the stage known as *decline*, *defervescence*, or *resolution* ensues. This may be rapid (*crisis*) or gradual (*lysis*).

Various theories are suggested to explain why the microbes tend so often to die out in each case, as that the high temperature of the body kills them, or that the multiplication of the poison interferes with their

growth. *Convalescence* is the period in which the body gets rid of the effete products, and restoration of the various functions is re-established. *Sequelæ*, however, sometimes occur after the disease appears to have been cured; these are probably due to the action on the tissues of poisonous products which have not been eliminated or destroyed—perhaps on account of their late production, or sometimes to secondary infections. *Death*, however, may occur before a disease has run its course.

The terms *endemic* and *epidemic* are used in connection with preventable diseases—the former to imply that the disease is restricted within certain areas, depends on local or localized causes, and has a tendency to persist in the district; the latter to describe a disease which suddenly appears and spreads widely and rapidly, but its prevalence is usually of limited duration. The two conditions, however, may pass into one another—*e.g.*, plague, yellow fever. The term *sporadic* is applied to diseases which occur in isolated cases.

It is unnecessary here to describe the history and course of communicable diseases, as these, with their geographical distribution, have been or can be acquired from text-books and experience. Attention, however, will be called to certain points, especially in connection with differential diagnosis, as mistakes are sometimes made even by experienced men.

The table on p. 186 has been drawn up to exhibit the incubation stage of various diseases and the time that isolation is necessary. The figures are taken from a large number of observers, those relating to the incubation stage being the longest, shortest, and usual length of that period.

Typhus Fever.—Long-continued overcrowding, with defective ventilation and personal filth, are the conditions which favour the outbreak of this disease, which, beginning among the poor, may spread throughout all classes of a community. It is important that the early cases be recognised and promptly isolated in large, airy rooms; by this means the poison which proceeds from the lungs and skin, and is very potent under appropriate conditions, is rapidly diluted by diffusion through the atmosphere.

Name of Disease.	Length of Incubation Period.	Usual Length.	Length of Infection.
Typhus	1 to 21 days	12 days	3 to 4 weeks.
Enteric	1 to 28 days	15 days	4 to 8 weeks, until diarrhœa ceases.*
Relapsing fever	Hours to 10 days	6 days	Until relapses cease.
Cholera	Hours to 10 days	Under 72 hours	Throughout attack; greatest during height of disease.
Epidemic diarrhœa	—	10 to 12 hours	—
Yellow fever	Hours to 15 days	Few hrs.	—
Scarlatina	Hours to 7 days	2 days	8 weeks, until end of desquamation.†
Measles	7 to 14 days	12 days	3 to 4 weeks, until end of desquamation.
Rötheln	4 to 21 days	15 days	2 to 3 weeks.
Small-pox	5 to 14 days	12 days	3 to 6 weeks; until every scab has fallen off.
Chicken-pox	4 to 18 (27) days	10 days	4 weeks; until every scab has fallen off.
Diphtheria	1 to 12 days	5 days	3 to 8 weeks; until all discharges have ceased.
Influenza	2 to 7 days	2 or 3 days	(?) 14 to 21 days.
Whooping-cough	7 to 21 days	14 days	6 weeks or longer.
Contagious pneumonia	1 to 20 days	6 days	—
Mumps	4 to 24 days	18 days	3 to 4 weeks.
Erysipelas	1 to 8 days	4 days	Until end of desquamation.
Puerperal fever	2 to 6 days	—	—
Rabies	6 days to 2 years	6 weeks	Disease usually develops within 4 months.
Plague	2 to 8 days	—	—

* It is now recognised that the *B. typhosus* may persist for several weeks in the urine.

† If there is otorrhœa the period of infectivity may be prolonged.

Typhus is most prevalent during the colder months of the year. *Mortality:* the death-rate is from 12 to 18 per 100 (hospital cases).

Typhus may be mistaken for enteric fever, measles, meningitis, and delirium tremens.

It is distinguished from enteric by the absence of diarrhœa, by the characteristic eruption, and by the character of the temperature chart.

The symptoms which serve to distinguish typhus from the other diseases are:

Typhus.	*Measles.*
No early symptoms.	Catarrh of air-passages.
Not confined to children.	Confined to children.
Adults first, children after.	
Character of eruption.	Character of eruption.
Time of development.	Time of development.

Typhus (in advanced stage).	*Intracranial Inflammation.*
Sensibility blunted.	Sensibility acute.
Headache only early.	Headache throughout.
Headache and delirium do not occur together.	Headache and delirium generally go together.
Pulse more feeble.	
More muscular tremulousness.	

Typhus may be differentiated from delirium tremens by the history, and by the condition, of the skin and tongue; muscular tremors occur in both, early in delirium tremens, late in typhus.

During convalescence from pneumonia there may be a typhus-like rash, but it disappears without any further symptoms. Typhus is sometimes accompanied by bronchial catarrh, or by hypostatic congestion of the lungs.

The destruction of unhealthy property, the carrying of great thoroughfares through the densest aggregations of houses, and the opening up of breathing spaces enabling the air to have free movement, have almost eradicated typhus from many of our large towns. The average annual death-rate due to this disease is now only 0·005 per 1,000.

Simple continued fever, or **febricula,** in a small proportion of the cases, is probably due to slight poisoning by leucomaines; the great number, however, are better described by the Registrar-General as *ill-defined fever*, and may be undiagnosed cases of typhus, acute tuberculosis, septicæmia, intermittent fever, pneumonia of a low type, and, sometimes, enteric fever. The returns of deaths ascribed to this cause show an almost annual decrease. In 1891 they were at the rate of 0·011 per 1,000 living.

Relapsing or Famine Fever (apparently identical with the synochia of a former century).—The *Spirillum Obermeieri* is believed to be the immediate cause of this disease, as it is found in the blood in large numbers during the relapses, but is absent (in spirillum form, at least) in the periods of apparent convalescence. The predisposing causes are extreme want, depression, and overcrowding. It occurs only as an epidemic; all ages are affected. It is more common in children than typhus is. One attack of relapsing fever does not confer immunity from subsequent attacks of this disease. According to Dr. Murchison only 4·03 per cent. of those attacked die.

Epidemic Diarrhœa.—Diarrhœa is a prominent symptom in different complaints, and is frequently due to the presence of some irritant in the intestinal canal. Children are especially liable to be attacked with diarrhœa when changes are made in regard to diet, as at the time of weaning, or when improper food is given; but in summer this tendency is so greatly increased (adults also being affected) that such names as epidemic, choleraic, or infantile diarrhœa, summer or English cholera, have been given to it. While this disease prevails quite as much (if not more so) among adults as among young children, yet the mortality is almost exclusively confined to the latter, and equals one-tenth of all the other causes put together. In England and Wales the average of ten years' death-rate at all ages from this cause is 0·6 per 1,000. While it is true that improper feeding of children is a factor in its causation, and that putrefactive changes occur more rapidly in food in warm than in cold weather, and might be sufficient to set up diarrhœa, yet it is now believed to

be chiefly due to bacteria, and it is probable that they act in this as well as in Asiatic cholera by producing poisons in the intestine. In Sir Lauder Brunton's opinion, 'probably much of the diarrhœa which occurs, especially in children, after the use of milk, is due to the formation of tyrotoxin, or other more or less poisonous products, by decomposition of the milk in the intestine itself'; and as milk appears to be an excellent breeding-ground for septic and other organisms, it is easy to explain the reason why infants who are breast-fed have a much greater chance of escaping diarrhœa than those who are fed by hand. That the risk of bacterial inoculation is practically small in the former is shown by statistics collected by Dr. Hope of Liverpool. He found that in 463 deaths from diarrhœa of children under six months only twenty-three had been fed from the breast alone.

The following is the working hypothesis or provisional explanation which Dr. Ballard makes the basis of certain practical suggestions for the prevention of epidemic diarrhœa :

'That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism not yet detected, captured, or isolated.

'That the vital manifestations of such organism are dependent, among other things, perhaps principally, upon conditions of season, and on the presence of dead organic matter, which is its pabulum. That, on occasion, such micro-organism is capable of getting abroad from its primary habitat, the earth, and, having become air-borne, obtains opportunity for fastening on non-living organic material, and of using such organic material both as nidus and as pabulum in undergoing various phases of its life history.

'That in food, *inside* of as well as *outside* of the human body, such micro-organism finds, especially at certain seasons, nidus and pabulum convenient for its development, multiplication, or evolution.

'That from food, as also from the contained organic matter of particular soils, such micro-organism can manufacture, by the chemical changes wrought therein through certain of its life processes, a substance which is a

virulent chemical poison, and that this chemical substance is in the human body the material cause of epidemic diarrhœa.'

Certain factors have been noted as having an important bearing upon the development of diarrhœa, the chief of these being the nature and temperature of the soil.

1. *Nature of the Soil.*—A high mortality occurs on loose soils, such as those composed of sand, gravel, marl, or marl with clay, which are easily permeated by water and air, and especially when such soils are contaminated with organic animal matter. Epidemic diarrhœa is especially prevalent upon 'made' soils. Excessive dryness or wetness of the soil is unfavourable to diarrhœa.

2. *Temperature of the Soil.*—The atmospheric temperature has very great influence; but it is exerted indirectly, as Dr. Ballard found that the mortality did not increase until the mean temperature recorded by an earth thermometer at a depth of 4 feet from the surface has attained to about 56° F.—no matter what the temperature previously attained by the atmosphere, or recorded by a thermometer at a depth of only 1 foot from the surface, may have been. The mortality rises and falls with the 4-foot thermometer. It usually begins to rise rapidly in the middle of June, attains a maximum towards the beginning of August; the fall begins slowly in August, becomes more rapid in September, and recovers its ordinary rate by the end of October. The years 1887 and 1888 afford an illustration of the effects of temperature. In 1887 the mean temperature of the third quarter was 61° F., and the mortality from infant diarrhœa was high, while in 1888 the mean temperature was 57·6° F., and the number of deaths less than half those in the previous year. Minor influence on the mortality is exerted by the amount of rainfall, rise or fall of ground-water, wind, or comparative calm, and by elevation above sea-level, according to the way in which they hasten or retard the rise of temperature, or affect the wet or dry condition of the soil.

Diarrhœal mortality is also favoured by density of population or of buildings upon any given area. Restricted

circulation of air *about* or *within* dwellings, domestic darkness and general dirtiness and fustiness of dwellings, emanations from sewers, cesspools, middens, privies, and dust-bins, filthy accumulations, polluted drinking-water and food-supplies, especially milk, and everything about a house which tends to lower health and vitality exert a baneful influence, and should be remedied.

Dr. Ballard recommends subsoil drainage, concreted sites for dwellings, free ventilation, daily scavenging, proper drainage, and special precautions to protect the milk supplies from contamination (aerial or otherwise) both before and after it reaches the consumer.

Asiatic cholera is often epidemic in different parts of India. It has been imported into this country on several occasions by travellers coming direct from infected places and by clothes which have been exposed to the poison; its usual method of distribution is through the agency of the drinking-water, especially if that be impure. When introduced into temperate countries a few isolated cases appear in the autumn, and then the disease disappears, to become an epidemic in the ensuing summer; the conditions favourable for diarrhœa are also suitable for the development of cholera. To the comma-shaped bacillus discovered by Koch has been attributed the causation of cholera; but Sir Lauder Brunton thinks it probable that the symptoms are not caused by a poison formed by its action alone, as none of the poisons produced by pure cultivations of the bacillus have produced exactly the symptoms of cholera. Whatever the poison may be, it is chemical in its nature, and may act independently of the microbes which produce it; the symptoms of cholera are exactly those of poisoning by muscarin or ptomaine evolved from other putrefactive bacteria. The comma bacillus is to be found in the rice-water dejections which characterize the complaint; it probably develops in loose moist earth or in water.

Enteric or **typhoid fever** depends on the presence in the body of a rod-shaped actively motile bacillus strongly resembling the *B. coli communis*, but more abundantly supplied with flagella, which has been isolated, originally by Eberth, from the fæces and urine of enteric patients. According to Brieger it produces a poison which he calls

typhotoxin. In many particulars the same conditions which favour the development and spread of diarrhœa and cholera also obtain in connection with enteric fever. Soils impregnated with animal filth, cesspools, sewers improperly laid, seldom cleansed, and containing deposits for long periods, and water-supplies contaminated with organic matter, furnish suitable localities for the development of the bacillus (this is one of the bacilli which do not produce spores); and it is *out of* rather than *in* the human body that the infectiveness of the poison is developed. This is shown by the rarity with which nurses, whose duties expose them to the influence of the poison in its recent state, acquire the disease, and by the rapidity and ease with which an epidemic is occasioned when the poison finds access to the water-supply to a community.

That a certain temperature also is required in this, as in these other diseases, is shown by the prevalence of the complaint in the autumn months, when the deeper layers of the subsoil have become heated.

Pettenkofer's opinion is that the deaths from enteric fever are greatest when the level of the ground-water is lowest; but as the increase in the mortality frequently follows a rapid sinking of ground-water after an unusual rise, it is highly probable that the fluctuations of the ground-water merely serve to promote the growth of the enteric bacteria, by adding or removing moisture, and by influencing the temperature and composition of the ground-air. At the same time it is possible that the movement of ground-water into or from impure soil may carry the germs of enteric fever into the drinking-water, especially when derived from wells, or may be the means of forcing infected ground-air into houses.

While the poison of enteric fever is usually conveyed to the human body through the water-supply, yet it sometimes finds entrance by being inhaled with the breath, as in the effluvia from cesspools, stopped drains, filthy closets, soil-pipes, ventilating shafts ending near windows. Professor Finkler, of Bonn, has lately given an account of a series of cases which spread only among those who had come into direct contact with patients or their linen. It is quite possible that clothes may be stained with the

discharges, which, becoming dry, give off the germs into the air.

The experience of the recent war in South Africa has shown that flies are a potent agent in the spread of enteric fever.

Milk is a common means of conveying the poison ; it may be contaminated by the water used to dilute it, by the utensils in which it is contained being washed with such water, or by the poison being taken up from the air.

Water also may absorb the poison, as when the cistern overflow-pipe is connected with the water-closet. The disease may also be spread by the internal use of ice and ice-creams, as researches have shown that ice may contain large numbers of bacteria, one observer having succeeded in growing enteric germs after they had been frozen in ice 103 days. They are killed by exposure to a temperature of 60° C.

It has been sought to prove a connection between diseases affecting cattle and human typhoid, but domestic animals do not appear to be susceptible to the disease.

Swine-plague, the so-called hog-typhoid, bears no relation to human enteric ; the patches of ulceration which occur in the intestines have no connection with lymphatic follicles.

Dr. Murchison's statistics show that the liability to contract enteric fever is about equal at all ages up to about twenty-five, and from that age onwards it rapidly and uniformly diminishes.

From 8 to 25 per cent. of the recorded cases end fatally; that these figures are too high is possible, as many cases are so mild as not even to be recognised. The death-rate is less below the age of twenty than above it, is highest in patients about fifty, and almost nil in young children (London Fever Hospital).

Statistics show that there has been a general tendency to decreased mortality during the last two decades, the average for the first being 0·32 and for the second 0·19 per 1,000 living in England and Wales.

Differential Diagnosis.—The diseases with which enteric fever may be confused are : Simple gastric catarrh, simple

continued fever, acute tuberculosis, tubercular meningitis, typhus, scarlatina, influenza, measles, pneumonia, and typhlitis.

In simple *gastric catarrh* the temperature chart should guide.

In simple *continued fever* there is an absence of the eruption, abdominal symptoms, and the characteristic temperature.

In *acute tuberculosis* the above are also absent—the physical signs should be observed as to dulness on percussion of the apices of the lungs, as to auscultatory changes, and as to alteration in the rhythm of the breathing and cardiac action; in acute tuberculosis the breathing becomes more rapid relatively to the heart's action. In enteric there is often dulness at the base of the lungs.

Tubercular Meningitis in Children.	*Enteric Fever.*
Tongue—keeps moist.	Yellow with red edges, and soon becomes dry.
Thirst—normal.	Increased.
Vomiting—frequent.	Rare.
Abdomen—retracted (often).	Full.
Bowels—constipated.	Loose. or constipated
Headache—severe.	Not great.
Intolerance of light and squinting.	Spots on skin.

In regard to *typhus*, the points to be observed are the eruption, date of its appearance and duration, the abdominal symptoms, and temperature chart.

Scarlet Fever.—Sometimes in enteric a rash resembling that of scarlet fever comes out before the proper time for the appearance of the lenticular spots, but the condition of the throat, temperature, date, etc., should decide.

Measles.—In 1887 eight cases of measles and rötheln were admitted to the Western Fever Hospital, London, certified as enteric fever. If the rash be deferred, or if pneumonia or diarrhœa be present, the condition might

be suggestive of enteric; the temperature, age, method of onset, and surrounding circumstances should be examined.

Pneumonia.—Enteric fever has been mistaken for pneumonia (and *vice versâ*), when pneumonic symptoms have been a prominent part of the disease.

Typhlitis and Perityphlitis.—History, onset, temperature and condition of bowels, etc., serve to distinguish.

Eberth's bacillus may be detected in the urine at a very early stage of enteric fever, and persists for a variable period during convalescence. Urotropin administered by the mouth is a valuable disinfectant of the urine,

The test now relied on to establish a positive diagnosis of enteric fever is Widal's reaction, which depends on the fact that the blood-serum of a patient suffering or recently convalescent from enteric fever contains bactericidal protective bodies which produce agglutination or 'clumping' in a dilute emulsion of typhoid bacilli. Analogous reactions, depending on the same principle, have been obtained in the case of cholera and other specific fevers.

Some bacteriologists have maintained that the *Bacillus typhosus* is a descendant, modified by evolution and changes due to environment, of the *B. coli communis*, a constant inhabitant of the human intestine. This theory has yet to be proved. At present the cultural differences between the two varieties are well marked and apparently specific. The essential differences between the two manifested by cultures were as follows: The typhoid bacillus is distinctly more cylindrical than the *B. coli*; its motility is decidedly greater; it grows less quickly than the *B. coli* on the surface and in the depths of nutrient gelatine, as also in gelatine plates; when growing on the surface of gelatine, either in tubes or in plates, it forms a peculiar iridescence which is not observed on similar cultures of the *B. coli*; it does not form gas-bubbles in gelatine shake cultures; it does not curdle milk; it grows well in broth, but does not produce the *indol reaction* (which depends upon the action of nitrous acid upon indol, resulting in a rose to deep-red coloration); it grows well in 25 per cent. gelatine, but, unlike *B. coli*, makes the

gelatine uniformly turbid in as short a time as after twenty-four hours.

Enteric fever possesses a number of synonyms in popular use, as typhoid, bilious, or gastric fever, infantile remittent, abdominal typhus, worm fever, etc.

It is important to note in regard to these 'filth' dis eases that the saprophytes contained in the soil have the power of destroying these pathogenic germs—probably it is when the soil is too wet or too dry that the saprophytes themselves may be destroyed or weakened, so that the pathogenic germs acquire an ascendancy. As these saprophytes live only in the upper layers in the soil, organisms buried below would not be influenced by them.

Diphtheria, or **membranous croup**, is associated with the development of an organism called, after its discoverers, the Klebs-Löffler bacillus. A positive diagnosis of the disease is now generally made to depend on the recognition of this bacillus.

This bacillus develops *on* the mucous surfaces of the body, and on any wounded area of skin; it does not invade the tissues, and is incapable of multiplication subcutaneously; in its growth it produces a ferment resembling the diastases in nature, which, when absorbed, digests the proteids of the body, forming albumoses and a toxic acid. These digested products cause fever and depression, and in extreme cases death. They are the cause of the nerve-lesions and subsequent paralysis and fatty degeneration of muscles.

The spread of diphtheria is undoubtedly favoured by dampness, defective drainage, polluted water-supply, *personal communication*, especially among school-children; houses overcrowded and with impure air; accumulations of manure, etc., about a house; want of isolation and disinfection of clothing; by the milk-supply. It seems probable that the lower animals may suffer from this disease and transmit it to human beings; among those suspected are pigeons, rabbits, chickens, turkeys, cattle, dogs, and cats.

The effects of cold and damp, causing catarrh of the mucous membrane, must also be kept in mind as a predisposing factor. The frequency also with which diphtheria follows attacks of other diseases affecting the naso-pharynx

or larynx, as scarlatina or measles, may be similarly explained. Indeed, any cause that tends to render the condition of the throat abnormal may produce a suitable nidus for diphtheria.

There appears to be no doubt that diphtheria may occur in a minor form of illness difficult to recognise until it is communicated to others in an intensified degree. While it is possible that an apparently simple tonsillitis may be diphtheritic in its nature, follicular inflammation of the tonsils or membranous angina may be mistaken for the more serious disease.

On this point Thorne-Thorne has laid down :

'That prevalences of recognised diphtheria are commonly associated, in their beginning, during their continuance, and after their apparent cessation, with a large amount of ill-defined throat illness, and that fatal attacks of diphtheria in many localities get registered as croup, laryngitis, etc.

'That there is reason to believe that attacks of so-called sore throat exhibit under certain favouring conditions a progressive development of the property of infectiousness, culminating in a definite specific type, which is indistinguishable from true diphtheria.

'That, apart from susceptibility, "school influence," so called, tends to foster, diffuse, and enhance the potency of diphtheria, and this, in part at least, by the aggregation of children suffering from that "sore throat" which commonly is prevalent, antecedent to, and concurrently with definite diphtheria.'

Some bacteriologists maintain that the so-called pseudo-bacillus is merely an attenuated form of Löffler's bacillus, especially as the virulence of the true bacilli varies considerably in individual attacks. If this be so, it may be possible for it to regain its virulence in an environment suitable for its development.

After the disappearance of all membrane and apparent recovery from disease, Löffler's bacillus may persist in the mucous membranes, and be capable of infecting others. Severe outbreaks in schools have arisen from the unsuspected persistence of membrane in the nares or fauces of children who had apparently completely recovered from the disease.

Diphtheria Antitoxin.—In cases of diphtheria in a house or institution, especially when the patient cannot be removed, the inoculation of other inmates exposed to infection with diphtheria antitoxin may be resorted to with good effect, to prevent the spread of the disease. The protective period extends over thirty days, and within that time is almost absolute.

Epidemic Influenza.—In every year, during changeable weather, cases of catarrhal affections of varying intensity are by no means uncommon, but influenza is a disease which comes only at irregular intervals, spreading rapidly from one country to another, and lasting in each district from six to eight months. It prevails at the same time in countries on both sides of the globe quite irrespective of season.

Pfeiffer has discovered a bacillus in the expectoration from all cases of influenza. The rapidity of the spread of influenza points to the air as the medium by which the contagion is carried, being given off in the breath of affected persons, so that the disease may be carried from an infected district to one not so by visitors suffering from an attack ; it is also possible that the contagion may be carried by means of letters in transit from one country to another.

No age or sex is free from liability, and even horses and other domestic animals may suffer. The mortality is small, about 2 per cent., and is chiefly among the aged or those already suffering from cardiac or pulmonary troubles. This small mortality, however, adds considerably to the death-rate, as the disease attacks such a large number of people. During influenza epidemics, moreover, there is always noticed a considerable increase in deaths from pulmonary complaints. In certain cases the diagnosis from pneumonia or typhoid fever can only be confirmed by bacteriological examination. Pneumonia is often a concomitant of influenza.

The incubation stage during the late epidemic appeared to last two days. The disease affected people in three different ways—in one form the respiratory tract was most affected ; in another gastric and intestinal catarrh was the principal feature ; while a third form was characterized by severe muscular pains, resembling rheumatism.

All three forms were generally accompanied by much nervous depression. The bacillus appears to produce a toxin having special affinity for the nervous system.

Relapses were very apt to occur after apparent recovery if there was too early exposure to cold. In some cases an erythematous rash was present.

The only means to prevent its spread from individual cases is isolation and the use of aerial disinfectants in the rooms occupied.

Scarlet Fever (Scarlatina).—The etiology of scarlet fever has been the subject of much discussion. It is now decided that the cause is due to an eminently contagious body, probably the streptococcus described by Klein; that both man and the lower animals may be affected with it; that the disease is spread by all matters passing from the bodies of those affected, but especially by those which come from the lungs, throat, nose, and skin; that the contagium may be carried by the air unchanged through small distances, as through a house, without loss of power; that it clings to clothes, and may retain its vitality over very long periods; that milk is often the means by which scarlet fever is disseminated—and here the difficulty occurs and still waits solution, How does the poison get into the milk? Until what is known as the Hendon inquiry (Local Government Board Report by Mr. Power, March, 1886), this question was answered by saying that particles of skin containing the poison fell into the milk and were conveyed to the consumer—and that is no doubt one way—but Mr. Power, in consequence of an epidemic springing up in North London among persons supplied with milk from a dairy at Hendon, where certain of the cows were found to be suffering from small vesicles and ulcers on the udder and teats (now called the 'Hendon Disease'), started the theory that the milk of those cows produced scarlet fever in the human subject. Professor Klein found in them the same streptococcus as in scarlet fever, and calves fed on sub-cultures established from human scarlatina obtained the Hendon disease. It is, however, still a matter of doubt whether infected milk derives its infection directly from the diseased animal (as would other secretions of the body) or indirectly from the hands of

the milker by the poison falling into the milk either from the inflamed teats or from his own desquamating cuticle. Each or all of the three methods is possible.

Scarlet fever is most prevalent in the autumn, the mortality rising highest in October and November. It adds on an average about 0·3 per 1 000 to the death-rate annually; but it is found that for about three years scarlatina is little prevalent, and then in the fourth year it will become epidemic. This is explained by the fact that during the first year of life the liability to this disease is almost nil; that it increases up to the fifth year, after which the susceptibility diminishes rapidly with every year of age, so that, as many children are attacked at one time in large towns, for the next few years after an epidemic the community is in a great measure protected. It is worthy of note that the rate of liability to the disease does not quite correspond with that of the mortality from it. The death-rate is highest in young children, averaging 3·5 per 1,000 under five years; it then diminishes to about a third between five and ten years, and continues to fall to the end of the twenty-fifth year, after which it increases to a small extent.

Measles (Morbilli) is confined in its attacks chiefly to children, but no age is altogether protected, as is evidenced by an epidemic which broke out in the Faroe Islands in 1846. The disease, which had not been known in the islands since 1781, was introduced by a sailor, and all but a few old people who had suffered from it at the earlier date were attacked. This is one of the diseases which raises largely the infantile death-rate, owing to its high degree of infectivity, the frequency of epidemics, the special susceptibility of children, and the relative seriousness of the disorder, which is greater than is commonly believed.

At all ages the mortality is about 0·4 per 1,000, and 90 per cent. of the persons dying are under five years of age. It has been suggested that of late years the type of the disease has altered, and that it has become a more serious disease. The cause of death is due chiefly to the irritation of the mucous membranes, producing laryngitis, bronchitis, diarrhœa, etc., but these are mainly developed among the children of the ignorant and careless; as soon

as the rash has disappeared the child is allowed to run about out of doors, and, as the disease is most prevalent in the winter and spring, it proves to be then most fatal also. It is infectious during the stage of invasion. The contagium is given off from the skin and breath, and clings persistently to clothes; hence the disease is spread more by contact of one child with another than at long distances through the air.

Rötheln, rubeola, rose-rash, or German measles, while resembling both measles and scarlatina in its symptoms, yet is incapable of inducing either of these diseases or of protecting from a subsequent attack of either, nor is a patient who has had both protected from this. Measles or rötheln may be confused with small-pox, enteric fever, scarlatina, syphilis, the rash produced by gastric derangement, the rash induced by the use of drugs, such as cubebs, copaiba, iodide of potassium, sulphate of quinina, and with simple erythema.

Differential Diagnosis.—Cases occur in which it is difficult to make a differential diagnosis between measles, röthlen, and scarlatina. It has even been maintained of late that there is a 'fourth disease,' specifically different from any of the above. During the early stage the temperature, premonitory symptoms, and the early rash of scarlatina should decide. As to the eruption, the date of appearance, situation, colour, and mode of grouping will guide. If the disease is seen late in the illness the character of the desquamation should be observed. In the case of rötheln, Clement Dukes appears to attach most importance to the rosy colour of the rash, and to the tenderness and enlargement of lymphatic glands throughout the body. Small-pox and scarlet fever have been confused, but the presence of sore throat and absence of pain in the back should assist at first, while the eruption, history of exposure, and subsequent desquamation should remove all doubts.

It should also be remembered that a red rash sometimes accompanies influenza, or may follow the exhibition of aperient enemata from the absorption of toxic products.

Whooping-cough (Pertussis), another disease affecting chiefly infants, bulks largely in the Registrar-General's

reports, the death-rate at all ages being 0·5 per 1,000 living, and 3·6 under five years of age. Like measles and scarlatina, with which it is often associated, it occurs in epidemics every few years. It is most prevalent and most fatal in spring. The infection is given off in the breath, but is also carried by the clothes. It gains admission to the body by the air-passages, generally beginning in the nose, so that it may readily be mistaken at the outset for ordinary catarrh.

Epidemic Pneumonia.—Although Fraenkel discovered a diplococcus, which he claims to be the microbe of ordinary pneumonia, yet other organisms seem to have the power of producing broncho-pneumonia; thus, in a virulent epidemic at Middlesbrough, Klein found, besides ordinary pyogenic organisms, a bacillus which he regards as specific. The poison spreads by the air, chiefly from the breath of patients, and is specially favoured by insanitary conditions.

The diplococcus of Fraenkel is sometimes found in the air-passages of apparently healthy subjects. Klein suggests that some particular condition of lung is essential before it produces pneumonia. This diplococcus is also found in certain cases of acute meningitis, cerebro-spinal fever, otitis media, and other affections of the nasal and aural passages, with or without pneumonia.

Variola (Small-pox) exists in this country in what may be called two forms, which require to be distinguished—viz., the natural and the modified.

Natural or *unmodified* small-pox is now comparatively rare, but in epidemic years still occurs, there being still in this country a relatively large number of unvaccinated persons, especially in towns which have neglected their statutory duties in regard to vaccination.

In the eighteenth century small-pox affected especially children under five years of age in the same way as scarlatina, measles, etc., and, like them, also recurred in epidemic form every three years, and, as all ages and both sexes were liable to it, very few escaped. The mortality was very high, more than one-third of those who suffered died, while many who survived lost their eyesight and hearing, or were disfigured in a way we have very little experience of nowadays.

Modified small-pox, or varioloid, occurs in those :

1. Who have had the disease before.
2. Who have been inoculated with the poison.
3. Who have been vaccinated.

The fatality in inoculated cases was only 3 per 1,000 cases, but the practice was so instrumental in spreading the disease throughout the country that it had to be prohibited.

Small-pox, which has been modified by previous vaccinations, does not attack children as a rule, and when it does the mortality is 85 per cent. less than it was in unmodified small-pox. It is chiefly persons over fifteen years of age that are now attacked.

The symptoms in the modified disease are similar to ordinary small-pox up to the eruptive stage, but after that it aborts. Small-pox appears to recur about once in ten years, being most prevalent during the first six months of the year, reaching a maximum towards the end of May. Epidemics of special severity recur about once in thirty years.

Diagnosis.—It is important that this disease should be properly recognised at an early stage, as affected persons may go about spreading the disease if unrecognised ; and, on the other hand, persons supposed to have it and sent into hospital are exposed to the infection, and if such persons are suffering from some other infectious malady, this new disease may be introduced among those recovering from small-pox and ill-fitted to resist a new infection. It is often a matter of great difficulty to decide the diagnosis, especially in abortive attacks. The diseases which have been wrongly diagnosed have been varicella, scarlatina, syphilis, measles, eczema, ecthyma.

Varicella is often mistaken for varioloid, and *vice versâ.* The distinctive features are :

Chicken-Pox.	*Modified Small-Pox.*
Initiatory fever—slight.	May be marked.
Eruption—in 24 hours.	On third day or later.
" is scattered.	Is in groups.

Chicken-Pox.	*Modified Small-Pox.*
Eruption all over body.	Most marked on face and wrists.
,, often well marked between scapulæ.	
,, spot is not hard.	Feels like shot.
Vesicle formation in a few hours.	Delayed.
,, umbilication, appears late, only during the drying up of the vesicle.	Umbilication well marked, in the early stage, disappears with complete suppuration.
,, is thin walled.	Is thick walled.
,, irregular in shape.	Regular in shape.

Dr. Boobyer states that the presence of a peculiar polished, absolutely circular and sometimes rayed scab is an unmistakable sign of small-pox, and is well seen in the modified and aborting cases forming up from the bottom of the vesicles as early as the third day of the eruption.

Syphilis may be mistaken for small-pox in the early stage of eruption; many of such mistakes have resulted from the person suffering from a feverish catarrh at the same time, and concealing the truth as to having had a chancre, either wilfully or from a want of knowledge of the language, as in the case of foreign sailors.

Hæmorrhagic or confluent small-pox may be mistaken in its earlier stages for measles.

The *infection* of small-pox exists throughout the whole course of the disease, and is contained in all that leaves the body; it remains effective for long periods, and may be conveyed by clothing. It may also be transmitted by dead bodies, bedding, books, etc. It is sometimes imported in bales of rags to the workers at paper and shoddy mills.

It is believed by some that the contagium of small-pox can be conveyed for considerable distances by aerial diffusion, independently of human intercourse. In this respect the infectivity of small-pox is more potent

and far-reaching than that of any other disease. The ordinary methods of isolation from human intercourse and the chances of direct personal infection that may be sufficient for isolation hospitals dealing with such diseases as scarlatina and diphtheria are not sufficient in respect of small-pox hospitals. To minimize risks, the Local Government Board require that these should, if possible, be erected not less than a mile from any considerable centre of habitation.

The bacteriology of small-pox has not yet been completely worked out, but it is probable that a minute sporing bacillus, staining with great difficulty, which has been discovered by Klein in lymph of a certain age, will eventually be proved to be the specific etiological agent in both variola and vaccinia. Copeman has independently discovered a small bacillus in vaccine lymph which is believed to be identical with that found by Klein. The researches of these two workers may be said to have established the fact that vaccinia and variola are cultural modifications of an identical contagium, attenuated in the case of vaccinia by transmission through the body of an animal relatively immune—that, in fact, vaccinia is true small-pox of the cow. Copeman has recently succeeded in inoculating a monkey with variolous matter, and from the resulting lymph has inoculated calves at several removes, finally obtaining a strain of lymph which, when inoculated into the human subject, produced typical vaccinia.

Vaccination.—We possess in vaccination a prophylactic against small-pox, which, if the operation has been recently performed, confers an almost absolute immunity against the risk of contracting the disease. The protection thus conferred gradually wears off, but a relative degree of immunity against the severer effects of the disease persists throughout life.

In the eighteenth century the risk of contracting small-pox was regarded as tantamount to a certainty, and the custom of 'inoculation' from mild cases, introduced from the East by Lady Mary Wortley Montagu in 1721, was enthusiastically welcomed and became almost universal, conferring as it did the prospect of contracting in a mild form and under favourable conditions of health, etc., a

disease which was regarded as inevitable. The fatality (2 or 3 per cent.) of the operation was by no means trifling, though far lower than that of 'natural' small-pox; but without doubt the practice assisted the dissemination of the natural disease. Inoculation was gradually superseded by vaccination, and was finally forbidden by law in 1840. Vaccination was introduced by Jenner in 1796, provided gratuitously by the first Vaccination Act of 1840, made compulsory in 1854, and systematically enforced from the time of the pandemic in 1871. In spite of attempts on the part of Government to enforce the law, the practice of vaccination has fallen into abeyance in many large towns, partly from the indifference of a generation which has grown up in ignorance of a disease, which, till the year 1901, appeared to many to have become extinct, and partly in consequence of an organized opposition to vaccination, proceeding from a party which tried to persuade the public that vaccination is not only not a true prophylactic, but is, they allege, in a serious proportion of cases, attended by detrimental effects on the health in the shape of erysipelas, inoculated syphilis, etc.

As a concession to this opposition, and as the outcome of the report of the Royal Commission on Vaccination, published in 1896, an amending Act was passed in 1898, substituting domiciliary for stational vaccination, prescribing the obligatory use of glycerinated calf-lymph in the place of arm-to-arm vaccination, abolishing repeated penalties, and providing that any parent or guardian making a statutory declaration before a magistrate of a conscientious objection to vaccination should be exempt from any penalty for neglecting to have his child vaccinated.

Glycerinated Lymph.—It has been shown by Dr. Copeman that if calf-lymph be intimately mixed with glycerine for a period of about three weeks all extraneous saprophytic organisms, moulds, cocci, etc., are destroyed without the protective properties of the lymph being impaired. In the laboratories of the Local Government Board lymph taken from certified healthy calves, under the strictest aseptic conditions, is ground to pulp, and intimately mixed with a certain proportion of chemically pure glycerine.

The emulsion is set aside, and from time to time gelatine plates are inseminated from it. Any moulds or extraneous bacteria that are present will appear as colonies on the plate. The lymph is not issued for use till the inseminated plates are found to be practically sterile. By this method such germs as the *Streptococcus erysipelatis*, the *Staphylococcus pyogenes aureus*, the tubercle bacillus, or any saprophytic organisms that may be present, are eliminated, but the contagious virus, whatever it be, of lymph is apparently unimpaired. Similar procedures are adopted in Continental laboratories, and there can be no doubt that the lymph now upon the market is a singularly pure article, and that the risk of accident from its use under due conditions of asepticity is reduced to a minimum.

The official memoranda issued by the Local Government Board on vaccination and re-vaccination should be procured, and the instructions for the proper performance of the operation carefully studied. Upon the care and efficiency with which vaccination is performed depends, to a great extent, the protection against small-pox, which is the one object to be secured. There is a strong feeling among many that the outcry against vaccination is in part due to the fact that it is not so thoroughly carried out as it ought to be, and thus persons supposed to be 'successfully' vaccinated and protected against small-pox contract that disease. The Local Government Board recommend that insertions should be made sufficient to produce at least four separate good-sized vesicles or groups of vesicles, not less than ½ inch from one another, the total area of which on the same day on the week following the vaccination should not be less than ½ square inch. The statistics of the London fever hospitals prove that this is a point of importance, the better and greater the number of the marks resulting from primary vaccination the fewer the cases; the severity of the disease varied in the same ratio.

The evidence collected by Marson from an experience of 10,661 cases strongly emphasizes the point :

Cases of Small-pox classified according to the Vaccination-marks borne by each Patient respectively.	Percentage of Deaths in each Class respectively.
1. Stated to have been vaccinated, but having no cicatrix	39·4
2. Having one vaccine cicatrix ..	13·8
3. Having two vaccine cicatrices ..	7·7
4. Having three vaccine cicatrices ..	3·0
5. Having four or more vaccine cicatrices	0·9
Unvaccinated	34·9

The final Report of the Royal Commission on Vaccination, published in 1896, affords overwhelming evidence of the efficacy of vaccination as a prophylactic against small-pox.

Under the heading of small-pox it was stated that certain changes had taken place as to the ages of the persons affected, and that epidemics were not so numerous or so fatal. These are changes which have not been exhibited by any other zymotic disease, and it is held that they are due to vaccination. The following statistics, presented by Dr. Ogle to the Commission, bear out this claim. The death-rate from small-pox was :

Per Million.

408 in 1838 to 1853 ; vaccination being optional.
223 in 1854 to 1871 ; „ compulsory, but not enforced.
114 in 1872 to 1887 ; „ enforced.

There was an epidemic in 1838, also in 1871, in which year also additional machinery was provided for carrying out the Act.

The only other factor which could produce a change in the death-rate would be improved sanitation, but while the general death-rate has declined 9 per cent., that of

small-pox decreased 72 per cent.; this decrease, moreover, has not been equally shared by people at all ages, as it should be if due to improved sanitation solely, for—

	Per cent.
In the first 5 years of life the mortality has fallen ...	85
From 5 to 10 " " " " ...	64
From 10 to 15 " " " " ...	27

Over that age the mortality has actually increased.

Improved sanitation certainly does not account for the fact that in epidemics such as that of Gloucester in 1895 small-pox in invaded houses seizes on the unvaccinated children, and passes over vaccinated children living under identical sanitary conditions, or for the fact that re-vaccinated nurses or attendants on cases of small-pox exhibit an absolute immunity to the disease. The statistics of the recent Gloucester epidemic may be quoted as a typical illustration of the degree of immunity of the vaccinated.

Total attacks, 1,979. Deaths, 434. Fatality, 22·2.

	Vaccinated (in infancy).				Unvaccinated.		
Age.	Attacks.	Deaths.	Fatality. per cent.		Attacks.	Deaths.	Fatality per cent.
Under 10	26*	1†	3·8	..	680	279	41·0
10 to 20	263	5	1·9	..	48	14	29·1
20 to 30	373	29	7·7	..	17	8	47·0
30 and over	549	85	15·4	..	23	13	56·5
Total	1211	120	Mean 9·9	..	768	314	Mean 40·9

During the course of the epidemic some 35,000 persons out of a population of 42,000 were vaccinated or re-vaccinated. The epidemic died out only when the un-vaccinated population became exhausted.

It was at one time believed that vaccination in infancy conferred immunity from small-pox for the whole period

* Twenty-five out of this twenty-six were over five years of age.

† This was a case of very doubtful vaccination. Of course, if it be eliminated, the fatality under ten years becomes nil, as it was at Middlesbrough.

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of life, but it is now known that it does not do so in all cases, and that in some the protective effect becomes exhausted in from ten to fifteen or more years; the above statistics show this conclusively. It is, therefore, that protection may be still further continued throughout life that re-vaccination is recommended at twelve years of age. The protective value of this practice is shown by the experience of nations differing in their small-pox death-rates as their laws for re-vaccination differ; good examples are afforded by the neighbouring States of Germany and Austria, in the former re-vaccination being enforced. In Prussia, since 1874, when both vaccination and re-vaccination became compulsory, the small-pox death-rate has fallen from 0·24 per 1,000 to 0·02 per 1,000, while in the army there has not been a death from small-pox since that date. Additional evidence of the immunity conferred by re-vaccination is afforded in our own country in the case of the London permanent postal officials and in the case of nurses in small-pox hospitals.

In the Homerton Small-pox Hospital during the years 1871-77, 366 nurses and attendants were employed. All had been re-vaccinated but one person, a housemaid. She was the only one who contracted the disease. The Highgate Small-pox Hospital possesses an unbroken record of fifty-eight years, during which no nurse or servant of the hospital contracted small-pox, with the exception of one person, a gardener, the only official who had escaped re-vaccination. On the other hand, nurses in other small-pox hospitals who have refused re-vaccination readily contract the disease; for instance, at Leicester in 1892-93, five out of the six unprotected nurses fell victims to the small-pox. No other disease shows an immunity among nurses remotely comparable to this.

On re-vaccination, if the persons be again fully susceptible, the local effect appears earlier than after primary vaccination, and the local and constitutional symptoms are more severe. If the susceptibility be less, then the results will be proportionately less. But the results also depend on the health of the person operated upon, and the age of the pock from which the lymph is taken, and upon individual idiosyncrasy.

It is not held that a person who has been vaccinated and re-vaccinated is absolutely certain not to be affected by small-pox, for 221 cases at Sheffield occurred among persons who had been re-vaccinated, and similar instances are quoted from other towns; but such cases might be reduced almost to nil if people did not defer re-vaccination until there is an actual alarm of small-pox, when most probably stored lymph has to be used, and perhaps no immunity conferred by its performance. Even in primary vaccination there are very grave doubts that the full measure of protection that is possible is given, and hence vaccination suffers much unmerited disparagement when the so-called 'successfully' vaccinated person contracts small-pox. The reason for coming to this conclusion is that sufficient importance is not attached to the way in which vaccination is performed by many medical men, who are too often guilty of making an insufficient number and area of insertions in order to gratify parents.

The use of glycerinated calf-lymph has abolished the risk —real, though very slight—of the inoculation of vaccino-syphilis, tuberculosis, or erysipelas along with vaccinia, which formerly attached to the practice of arm-to-arm vaccination. The operation should, of course, be performed under rigidly aseptic conditions, and the insertion wounds aseptically treated. Vaccination wounds exposed to septic conditions are liable during the progress of vaccinia to accidental infection from external conditions in the same degree as any similar wounds would be, no more and no less. The process cannot legitimately be held responsible for extraneous septic infections due to neglect of obvious precautions. The risks of death from vaccination have been reduced in Germany to 1 in 200,000.

Vaccination after Exposure to Small-pox.—As the incubation stage of small-pox lasts twelve days, to successfully combat its poison primary vaccination must be performed not later than the third day after exposure, re-vaccination not later than the fourth or fifth day.

Vaccination and re-vaccination are at present the best protection against small-pox that we have; until the disease has been finally and permanently banished not

only from this but from other countries, vaccination must continue to be compulsory, and everything possible should be tried to make it safer, more protective, and less objectionable to all classes.

Leprosy.—In 1874 Hansen of Christiania reported the discovery of fine rod-shaped bacilli as the cause of leprosy, and they have been detected since in all parts of the world in cases of leprosy, but have not been associated with any other disease; the presence of the bacillus causes the typical development of a migratory cell into Virchow's 'lepra-cell.' Some of the bacilli are motile, others not; many possess bright spores; when they enter the body they remain quiescent for long periods, probably in the lymphatic glands, but eventually the system becomes invaded by them in enormous numbers.

Soil and climate appear to have little influence upon leprosy; it has been noted, however, that a large number of the localities specially affected are low-lying, marshy, and on the sea-coast or banks of rivers; probably, also, the disease is more common among the ill-fed or dirty than among the well-to-do and cleanly (Bristowe). Although it thrives best in hot climates, yet, as from analogy we would expect, it is to be found also in cold countries where people huddle together in stove-warmed, badly-ventilated huts.

A disease known as granuloma or mycosis fungoides simulates leprosy very closely. It is believed to be dependent upon the action of microbes (J. J. Pringle).

Tuberculosis.—A disease which even now claims an annual mortality in England and Wales of 28 per 1,000—equal to one-seventh of the total death-rate—deserves especial notice in order that preventive measures may be taken to remove those conditions which produce or favour its continuance.

The tubercle bacilli, as described by Koch, appear as small rods, not quite straight, but with a tendency to curve, and show slight breaks or bends; they vary in length from half to quarter the diameter of a red blood corpuscle. The bacilli are generally found where the tubercular process is just beginning or where it is rapidly spreading; at later periods, when disintegration takes place in the surrounding cells, few bacilli are to be found,

for they have either been destroyed or have passed on to the stage of spore-formation, when the capability of staining is lost; their presence, however, can be inferred from the infective properties possessed by the cheesy substance containing them.

The bacillus must first gain admission to the body; this it may do :

1. By inoculation through any surface abrasion.

Direct infection by inoculation is known to occur on the hands of butchers, cooks, and others handling carcasses of tuberculous cows, and also amongst those who make post-mortem examinations on human tubercular corpses—*tuberculosis cutanea verrucosa* (Klein)—but only occasionally does this result in more than a local affection.

2. Through the genito-urinary mucous membrane.

3. Through the mucous membrane of the alimentary canal by the ingestion of tubercular diseased meat and milk. This question came to the front during 1889 in Glasgow, when Sheriff Berry decided that the flesh of animals affected with tubercle was not fit for food; this decision has since been upheld by the superior courts. In connection with this, Professor Klein has pointed out that susceptible animals contract the disease when the tubercle bacilli, in whatever form or from whatever source, are introduced into their digestive tract; that if in an animal the lungs and thoracic lymph-glands are the only organs visibly affected it is not to be assumed that the removal of these viscera will render the rest of the animal's body safe to be consumed as food. No part of an animal in which even a single organ is visibly affected with tubercle can be held free of the virus, for careful microscopical examination has proved that not only the lungs, diaphragm, lymph-glands, spleen, and liver are affected, but that the whole vascular system of the body may contain the bacilli, which are thus conveyed to the various tissues of the body. It is not, therefore, surprising that the secretions contain the bacilli; and as tubercular deposits in the milk-glands of cows are not of rare occurrence, a large amount of milk containing the poison must be consumed; it is in children, who are the chief consumers of milk, and that generally in an uncooked condition, that we find a preponderance of cases of tubercular disease

affecting the abdomen (tabes mesenterica, primary intestinal ulceration). Enormous quantities of meat from animals suffering from tuberculosis are undoubtedly consumed in this country, and apparently without danger, since the contagium is likely to be killed by the heat to which the meat is exposed during cooking, but there is always a chance that the bacilli in the inner parts of the meat may not be destroyed. In accordance with the Mosaic Law, tuberculous meat is not eaten by Jews, and though the poorer classes of them often live in circumstances likely to predispose them to consumption, yet they suffer from it comparatively seldom.

Koch has recently (1901) asserted that bovine and human tuberculosis are not mutually transmissible. A Royal Commission has been appointed to investigate the relation of the two infections.

4. Through the mucous membrane of the respiratory tract and air-cells of the lungs. After childhood, by far the commonest manifestation of the disease is in pulmonary and laryngeal phthisis. Cohnheim has pointed out that sputum, when it becomes dry on floors, walls, and handkerchiefs, is easily pulverized and blown about; if it contain bacilli, they will be set free by the drying, and be diffused throughout the air and readily inhaled into the lungs. The *Bacillus tuberculosis* is usually endogenic, and thrives best about blood-heat (36° C. to 38° C.); under 30° C. (86° F.) or above 42° C. it does not generally grow. Hence in temperate climates there is not so much chance of infection as in warmer regions; but rooms kept dirty, ill-ventilated, and overheated, afford the bacilli opportunities which our climate usually denies them. Cases, however, have been recorded in which living bacilli were found in the bodies of phthisical patients exhumed after an interval of two or three years; either the bacilli had accommodated themselves to the temperature of the earth, or the processes of decay in the bodies had evolved heat sufficient to maintain their growth. While bacilli, we know, are killed by thorough drying, yet well-dried sputum has retained its virulence certainly for forty, probably for a hundred days; this must undoubtedly be due to spores, which can also survive prolonged immersion in water, and in ice, temperatures up to 100° C., and

several hours' exposure to 1 in 1,000 solution of perchloride of mercury.

But, besides this real cause of the disease, there must be a soil fit for the bacillus to grow in, and without predisposing agencies this particular microbe would find it difficult to grow. It is by the removal of such agencies, together with the provision of means to prevent the entrance of the bacillus into the body, that this disease may eventually be dethroned.

Predisposing Causes.—(1) Heredity. It has long been recognised that the children of tubercular parents have a strong tendency to this disease, and numerous are the theories to explain what heredity is. Some condition of the tissues exists whereby they are unable to resist the attack of the bacilli, and we have been in the habit of recognising persons so affected as of a strumous disposition. M. J. Courmont has offered a plausible explanation why the children of a mother affected with tubercle should be susceptible to the disease. He made experiments with the soluble products manufactured by the tubercle bacilli and inoculated healthy animals with them; they did not appear to be affected, but he found afterwards, on inoculating them with bacilli, that they died in from fifteen to twenty-four hours instead of ten days. He suggests, therefore, that a tuberculous mother has these soluble products in her blood, and that they pass into the fœtal circulation, so that the child is born with tissues in a receptive state for infection. (The presence of soluble products being built into the child from the maternal blood might perhaps explain the causation of congenital syphilis.)

It is now known that the placenta does not always prevent the passage of micro-organisms from the maternal circulation to that of the child, but in children thus affected with tubercle the symptoms show themselves within a few weeks after birth.

(2) Influence of impure air, occupations, overcrowding. The amount of tubercular diseases may be taken as a guide to the sanitary and social condition of a district. Towns with back-to-back houses, bad ventilation, and overcrowding of persons within the houses, furnish the greatest number of deaths from this disease. Occupations

of an indoor and sedentary nature, especially if of a dusty nature, or if in such localities as described above, directly tend to produce phthisis by preventing proper use of the lungs, so that the air in part becomes stagnant and the circulation impeded. There is also the want of exercise in the fresh air and sunlight.

Among external influences having an important effect in respect to tubercular disease must be reckoned :

Moisture of Soil.—Dr. Buchanan, in the 'Ninth and Tenth Reports of the Medical Officer to the Privy Council,' has shown that when the soil has been drained by the introduction of sewers the death-rate from phthisis was immediately lessened, sometimes as much as 30 or 50 per cent.

Previous Diseases.—Many persons when in a low state of health, either from overwork, etc., or from previous illness, are liable to be affected with infectious diseases, as diphtheria, whooping-cough, enteric fever, etc. Such persons, then, are at that time also open to tubercular infection, conveyed into the system by meat, milk, or poultry, etc.

Prevention.—The measures to be adopted for the prevention of this disease are twofold :

1. By insuring that houses and workplaces shall be in good sanitary condition as regards drainage, cleanliness, efficient ventilation both by day and night, an adequate supply of light, and dryness of subsoil. Dr. Arthur Ransome has shown that tubercular dust exposed to sunshine lost its virulence in one hour ; kept in the dark with very little air it gave tubercle to guinea-pigs after thirty-five days.

2. By preventing access of the tubercle bacilli to the individual.

(*a*) This must be effected by proper inspection of all meat used for food, by stamping out the disease among cattle (as is being attempted in Denmark), by improving the conditions under which cows are housed (especially in towns), etc. In Berlin the meat of cattle in which more than one organ is affected, if in apparently good condition, is subjected to prolonged boiling at the municipal abattoir, and sold at a cheap rate. Dr. Sims Woodhead reports that, while ordinary cooking will sterilize the superficial parts of a joint, it cannot be relied upon to

sterilize tuberculous material included in the centre, especially if the piece be of more than 3 or 4 pounds weight. The least trustworthy method of cooking for this purpose is roasting before the fire, then comes roasting in an oven; boiling is the most efficient method in this respect. If there is any reason for suspicion as to its source milk should be boiled; indeed, some authorities prescribe this as a routine method.

(*b*) In the treatment of cases of consumption, means should be taken to collect the sputum in suitable vessels containing a disinfectant solution, or the expectorated matter may be received on pieces of rag or paper and burnt. Rooms should be well-ventilated and frequently cleansed. Body and bed-clothes should be boiled or disinfected before being washed by hand. (A case is recorded of a woman who was inoculated with tubercle on the skin of the hand through washing the clothes of her phthisical husband.) After death it would be well to have the room occupied by the patient disinfected by the direct application to the walls and floors of a 1 per cent. solution of chlorinated lime, by spraying or fumigating with formalin, and by thorough exposure to air and sunlight. Household pets, as cats, suffering from tubercle should be destroyed. A mother who is tubercular ought not to suckle her child.

Oriental Plague (*Pestis bubonica*). — A terrible recrudescence of this disease has recently devastated India, having been imported into Bombay from Hong Kong. Infection carried from India has occasioned localized outbreaks in Australia, South Africa, Egypt, Turkey, and in this country. The disease, which has a short incubation period, is characterized by sudden onset, with high fever, delirium, and prostration, and by bubonic swellings in the glandular regions, which generally suppurate. In a variable proportion of cases buboes are absent, and the disease takes either the pneumonic form, which is highly infectious, or the septicæmic, which is rapidly fatal. The mortality of the disease is very high, considerably over 50 per cent. Epidemics of plague are generally preceded and accompanied by epidemic mortality among rats and other rodents, especially squirrels. Birds and certain other animals are also liable to the disease. The direct

infectivity of the bubonic type of the disease from person to person is not very high. The infection appears to reside in the soil, to which it is generally conveyed by the excreta of plague-smitten rats. The explanation of the rapid spread of plague in India is to be found in the fact that the natives are a bare-footed and largely bare-skinned population, the floors of whose dwellings are spread with a compost of cow-dung, to which the infection is readily imparted by rats. A well-shod and clad community is but little likely to suffer from extensive outbreaks of the disease. The infective agent of plague is a bipolar staining bacillus, which does not appear to be capable of prolonged saprophytic existence. The most effective remedy against plague in India has been found to be wholesale evacuation of infected villages or quarters of towns, combined with subsequent evacuation of houses. The most important means to obviate the spread of plague to other countries is to prevent the importation of rats into ports by means of rat-guards on the hawsers, etc. It would be well so far as practicable to enforce the policy of rat-free ships advocated by Dr. Davies. International regulations against plague are settled by the terms of the Venice Convention of 1897.

Malaria in its various manifestations is now practically extinct in England, but is common in many countries, especially in warmer climates. It was discovered by Laveran that the disorder is due to the presence in the red blood-cells of a flagellate protozoön, the *Plasmodium malariæ.* Major Ronald Ross made the important discovery that this parasite is introduced into the blood by a particular species of mosquito, the *Anopheles.* The prophylaxis of malaria, as indicated by the discovery, is therefore (*a*) personal, to guard against the bites of mosquitoes by the use of mosquito-nets and wire-gauze windows, etc., to avoid camping on low ground, in the neighbourhood of stagnant water, or in the immediate vicinity of native quarters, and to fortify the system by prophylactic doses of quinine ; (*b*) communal, to obviate the generation of mosquitoes by draining and reclaiming marshy lands—a thin layer of paraffin floated on the surface of stagnant water will prevent the development of mosquito larvæ.

Other tropical diseases which may be mentioned are:

Yellow Fever.—An acute febrile disorder of tropical and sub-tropical climates, characterized by jaundice and hæmorrhages, including hæmatemesis, or black vomit. It has recently been demonstrated by Reed (*Journal of the American Medical Association*, February 16, 1901) that the mosquito *Culex fasciatus* serves as the intermediate host, transmitting the virus of yellow fever to the human subject.

Dysentery.—An ulcerative colitis, common in tropical and sub-tropical countries; due to the presence in the intestine of a protozoön, the *Amœba coli*, conveyed in impure drinking-water.

Dengue, or **Dandy Fever.**—A specific febrile disease, occurring generally in warm climates, characterized by severe articular and muscular pain, and in about half the cases by a transient erythema. In its clinical manifestations, high infectivity, and sudden onset, it somewhat resembles influenza, with which it has been sometimes confounded. The specific infective agent in Dengue has not at present been identified.

Beri-beri, which may be defined as epidemic peripheral neuritis.

Blackwater Fever, characterized by hæmorrhages from the kidneys.

Pyæmia, Suppuration, and Septic Diseases.—Four forms of micrococci are recognised as being associated with septic processes. Two of these Professor Ogston of Aberdeen describes as *Staphylococci*, occurring in large groups in masses resembling a fish roe or a bunch of grapes: microscopically, and in their effects on animals, they are alike; when cultivated, however, the *S. pyogenes aureus* produces golden yellow opaque colonies, and the other, the *S. pyogenes albus*, white opaque masses.

The third form, *Micrococcus pyogenes tenuis*, is only occasionally found.

The *Streptococcus pyogenes* microscopically resembles closely the micrococci connected with erysipelas and puerperal fever, but differs from each in the manner of growth and the effects produced in animals. These pus-producing organisms are either found alone or together;

sometimes in apparently similar cases different forms may be found.

Pyæmia may be divided into two groups: in one the symptoms are due to the absorption of alkaloids or other soluble products of organisms, which themselves may be non-pathogenic and may not enter the body; to this the terms *Septic intoxication*, *Septic poisoning*, and *Sapræmia* have been applied.

The other group is characterized by the presence of a well-defined centre, as a suppurating knee-joint or large wound of the soft parts, from which bacteria disseminate themselves throughout the system and form local deposits (embolisms), which become separate points of infection, from which a continuous supply of poisonous material is kept up: this is known as *Septicæmia*, or the *Micrococcus poisoning* of Ogston. Following Klein, the term *pyæmia* is now generally applied to such secondary foci of inflammation running a subacute or chronic course, and septicæmia, when the invasion is copious and universal.

Closely allied to these septic processes must be regarded erysipelas and puerperal fever. It is held by some that the micro-organisms producing these are identical while varying in virulence.

Erysipelas is included in the list mentioned in the Infectious Diseases Notification Act, thereby recognising its contagious nature. Fehleisen's researches have definitely proved erysipelas to be due to streptococci, which are found near the sharp edge of the inflamed patch; the development of these micrococci takes place primarily in the lymphatics, both of the skin and subcutaneous cellular tissue, and it is along them that they spread, blocking them up as they go.

Puerperal Fever is a term which appears to include several different conditions. According to some, any state of pyrexia, from whatever cause, occurring in the puerperal condition is called puerperal fever; but ordinarily the use of the term is restricted to manifestations resembling those met with in pyæmia.

Professor W. R. Smith, in an inquiry into the etiology of this disease, demonstrated the presence of an organism which, in microscopical and cultural peculiarities, re-

sembled the micrococcus of erysipelas and the *Streptococcus pyogenes*, but which has quite a different effect upon animals.

Whether this distinction shows definitely that there is a special microbe necessary to cause this disease, or that the ordinary form of *Streptococcus pyogenes* has become modified, it is difficult to say. The researches, however, of Winter and Döderlein showed that the vagina and canal of the cervix uteri normally swarm with organisms pathogenic in appearance and behaviour on cultivation, but which, on inoculation, gave only negative results ; but when the lochia was present in the vagina organisms were found which produced abscesses in animals. This tends to show that, according to circumstances, they may be in an attenuated or in a virulent condition.

Normally, organisms do not exist above the internal os either in the cavity of the uterus or in the Fallopian tubes, whether the female be puerperal or non-puerperal. When they do enter these parts, as by the hands or instruments of attendants, pyrexia is produced and the organisms thereby destroyed. The pyrexia results from the absorption of the toxic products, but true pyæmia may be set up by the entrance of septic matter into open bloodvessels. Dr. Braxton Hicks has pointed out that this might be produced by sudden movements or by sudden inspiratory efforts, as laughing.

Scarlet Fever and the Puerperium.—Some hold that scarlatina may produce a disease resembling septicæmia, but most are agreed that scarlatina always 'breeds true.' In puerperal cases the scarlet-fever poison might enter either by the usual channels or by the genital organs ; in the former case the disease would run its ordinary course, but in the latter the incubation stage is shortened (three to five days), the rash appears promptly, and the throat may not, or only slightly, be affected (Meyer, Boxall, etc.). Experience shows that puerperal women are not so liable to contract scarlatina as has hitherto been supposed, but when they do suffer from it the results are more likely to be serious. In the early stages of the disease pelvic inflammation and septicæmia may be merely coincidences with the scarlet fever, but in the later stages, especially when the poison has entered by the genital organs, it

would be due to secondary septic processes, similar to those that occur in the throat (secondarily) in non-puerperal cases.

Acute Rheumatism.—Dr. Newsholme has drawn attention to the epidemic and infective phenomena exhibited by acute rheumatism. Epidemics occur in or following years of sparse rainfall. This produces its effect by its influence in causing a warm and dry subsoil, usually with an exceptionally low ground-water—the years of highest level of ground-water never, and the years of lowest level nearly always, showing an excess of that complaint. Rheumatic fever is, he thinks, essentially a soil disease, having close relationships with erysipelas and other septicæmic diseases. Whether it is alternately parasitic and saprophytic or each case implies a fresh infection from the soil, is doubtful.

It has been shown that erysipelas, puerperal fever, and rheumatic fever exhibit similar annual curves, a dry and warm subsoil having a favouring influence on the specific contagion of the three diseases. The infective agent in acute rheumatism is believed to be a streptococcus.

Cancer, though not yet definitely recognised as such, presents many of the features of an infective disorder. Haviland has constructed maps, based on the Registrar-General's returns, tending to prove his thesis that cancer shows 'an infrequency in places characterized by elevated sites and limestone formations, or even by sites subject to floods, but within the immediate influence of calcareous rocks,' but betrays a high mortality in districts 'associated with flooded, low lying, and clayey areas.' He cites the Thames Valley as a typical cancer district in all respects. Not only does cancer cling to certain districts, but it has been shown to cling to certain houses, 'cancer houses,' and this is believed to be the true explanation of the apparent heredity of cancer. There is evidence to show that the discharges of cancer are capable of conveying the infection. The infectivity of cancer is strongly believed by many to be due to a specific germ, probably a protozoön. This has not yet been with certainty identified.

Anthrax (Charbon).—This disease is one affecting horses, cattle, sheep, and goats to a considerable extent

in some countries, and depends upon a large, freely sporing bacillus, of which mention has already been made. It is transmitted to men engaged in slaughtering the diseased animals, or in working with their hides and fleeces; hence the name *Woolsorter's Disease* sometimes applied to it. There are two principal varieties of the disease, dependent upon the manner in which the microbe finds entrance to the system: in one there is a characteristic *malignant pustule* present; in the other there is no external lesion, as the spores are taken into the respiratory (Greenfield) or alimentary (Koch) tracts.

To prevent the spread of anthrax, the isolation and slaughtering of infected animals is necessary, and the bodies should, when possible, be burned whole; otherwise they should be buried without being opened or skinned, as spore formation does not take place in the absence of oxygen. The discharges of infected animals should, when possible, be collected, disinfected, and burnt, and soil which may have been contaminated by such discharges should also be disinfected. Previous to hides, wool, or rags from affected districts being distributed in workshops, they should be disinfected by steam. Eating in the workshop should be forbidden. Mechanical ventilation, drawing the dust down from the person of the workman, should be insisted upon, the dust being collected and burnt. Special clothes should be worn by workers. The wools which have been proved most dangerous are of a dry nature, as mohair, alpaca, camel, Persian and Cashmere. The Van district in Armenia appears to be a special centre of the disease. Inoculation with attenuated virus has been tried successfully by Pasteur as a prophylactic.

Malignant Œdema is caused by an anaërobic bacillus found in soils containing putrid animal substances, as hay-dust, rag-dust, offensively smelling dust-bins, etc. (Klein). It has been demonstrated that surgical gangrene is caused by the same bacillus.

Tetanus is due to the bacillus of Nicolaier, which is found existing in earth, and finds access to the bodies of men and animals (especially horses about the hoof) either through open wounds or those caused by contaminated splinters, etc. The bacilli remain at the seat of puncture

and generate tetanin, which chemically resembles snake-poison. The bacillus is normally active under anaërobic conditions, but in association with other microbes, as the *B. coli communis*, is believed to acquire the power of growing aërobically.

Rabies.—Rabies is another of those diseases which may be transmitted from the lower animals to man, and of which mention has been made in an earlier part of this chapter in reference to Pasteur's treatment by protective inoculations. The disease usually develops within four months, but the incubation stage may, it is alleged, extend to two years. On the Continent it has been stated that four-fifths of the persons who are returned in official lists as having died from hydrophobia have really succumbed to a dread of the disease, or 'hyssophobia.' Rabies may be spread by wolves and cats as well as by dogs, but as it is chiefly from dogs that it is communicated in this country, Dr. George Fleming, C.B., has suggested the following precautions to be taken with a view to its total suppression :

1. All dogs to be muzzled for a period covering the extreme limit of the latent stage—say, one year. The presence of a muzzle prevents biting, and is evidence that the dog is cared for; when rabies is suppressed the muzzle can be abolished.

It may be noted here that the not very vigorously-enforced muzzling order of the end of 1885 reduced the mortality in London alone from twenty-seven to nine in the year 1886.

2. All dogs over three months to be registered and licensed; to wear a collar with owner's name and address, and a special number or mark affixed thereto.

3. All unlicensed and vagrant dogs to be destroyed.

4. Suspected animals bitten by rabid dogs to be destroyed.

5. Owners of dogs to be compelled to make declaration of the existence of the disease.

6. Owners to be responsible for damage inflicted by their dogs.

7. A period of quarantine to be enforced on all imported dogs.

By the Rabies Order of 1892 rabies is constituted a

disease within the meaning of the Contagious Diseases (Animals) Acts, the provisions of which are extended to dogs.

There are also a series of complaints depending upon higher members of the vegetable kingdom than bacteria; foremost among these may be mentioned **Madura-foot**, due to a small truffle-like fungus, known as *Chioniphe carteri*. **Actinomycosis** is caused by the ray-fungus or actinomyces, a parasite of cereals, especially barley. Under the microscope the little yellow grains are seen to consist of a number of radiating threads with swollen club-shaped ends, forming a sort of rosette. In cattle it affects the jaws by the formation of hard nodular tumours, and by the enlargement and induration of the tongue ('wooden tongue'). Occasionally the skin and lungs are similarly affected. Many cases have been recorded in which this disease has appeared in man, and, as first pointed out by Israel, it is characterized by the presence of metastatic abscesses in the lungs and elsewhere, containing this fungus.

Thrush is due to the *Oidium albicans* of the class of blastomycetes or torulæ; it is usually strictly confined to mucous surfaces, but cases are on record showing that it occasionally enters the circulation, and may give rise to serious visceral lesions, and even to multiple cerebral abscess.

Low forms of fever, with sore throat, sickness, and diarrhœa, have occurred from the presence of moulds and fungi growing in damp houses.

Species of *Penicillium*, *aspergillus*, *mucor*, etc., are capable of causing pathogenic, even fatal, mycosis in man. Salmon disease is caused by *saprolegnia* growing on the epidermis.

Various skin-diseases are attributed to the presence of vegetable parasites, as—

Molluscum contagiosum.

Tinea tonsurans, from the *Trycophyton tonsurans*.

Tinea favosa, from the *Achorion Schönleinii*.

Tinea versicolor, from the *Microsporon furfur*.

Erythrasma, from the *Trycophyton minutissimum*.

Alopecia areata; some cases may be due to *Microsporon Audouini*.

Animal Parasitic Affections.

Cestoda, or Tæniada—	*Larval form.*	*Host.*
Tænia solium.	Cysticercus cellulosæ.	Pig (measles).
„ mediocanellata.	„ bovis.	Ox.
„ echinococcus (dog and wolf).	Cysticercus (Hydatid).	Man.
„ marginata (dog).	Cysticercus tenuicollis.	Man.
Bothriocephalus latus.	Cysticercus.	Pike and eels.

Nematoda, or Round Worms—		*Habitat.*
Ascaris lumbricoides.		Small intestine.
Oxyuris vermicularis—thread-worm.		Rectum.
Trichocephalus dispar.		Cæcum.
Dochmius duodenalis.		Duodenum.
Trichina spiralis requires two hosts	Pig, Man	Muscles.
Filaria sanguinis hominis „	Mosquito, Man, etc.	Lymphatics and blood, etc.
Filaria medinensis or dracunculus—Guinea worm.		Cellular tissue.

Strongylus gigas and pentastoma denticulatum are rare.

Trematoda—	*Habitat.*
Bilharzia hæmatobia.	Abdominal veins and bladder.
Distoma, hepaticum, or fluke—eggs developed in water.	Liver.

CHAPTER X.

THE PREVENTION OF INFECTIOUS DISEASES.

This subject naturally divides itself into two heads: measures which are general and those which are special.

The *general* implies that permanent provision for securing the public health which is, or ought to be, the

aim of every sanitary authority; and, in the words of Sir George Buchanan, it is to be remembered that in proportion as a district is habitually well cared for, the more formidable emergencies of epidemic disease are not likely to arise in it.

A reference to statistics will show that while much has been done in this respect, there is much still to be done even in this country. At the commencement of Queen Victoria's reign the death-rate of London was 24 per 1,000; it is now 19 per 1,000; while in prisons where sanitary works have been completed epidemic visitations have been banished, and the death-rates of those who enter without developed disease upon them have been reduced to one-third of the general death-rates. In the army the same improvement can be shown, with great saving to the country both in men and money. In all the principal towns of the country there has been a material reduction in the death-rate during the latter half of the nineteenth century, amounting in some cases to as much as one-third or even one-half.

The *special* measures for the prevention of infectious disease include early notification (this is now provided for by law as regards small-pox, cholera, plague, diphtheria, erysipelas; scarlet, typhus, enteric, relapsing, continued, and puerperal fevers), isolation of the sick and disinfection of infected articles or houses, increased vigilance in the abatement of nuisances, in attention to the water-supply, in the prevention of overcrowding, the enforcing of greater cleanliness in houses and in public thoroughfares, house-to-house visitation, and the distribution among the people by handbills and otherwise of information as to what real precautions they can take, and what they should do on the appearance of symptoms. Sometimes it is necessary to close schools and other establishments wherein members of many different households are accustomed to meet.

Abroad, other nations still resort to a system of *quarantine*, to prevent cholera and other infectious diseases obtaining a footing in their country. Suppose a ship arrives at a foreign port having a case of cholera on board, they require the whole of the passengers and crew, healthy as well as sick, to be kept together until such time

as they can be declared free of disease. If cholera has already obtained a footing in a country, they endeavour to prevent people leaving the infected district by the establishment of *cordons sanitaires*; but these measures have always been found futile to prevent the spread of disease, and the example of this country is now being followed elsewhere. The practice here is, as far as possible, by improved water-supply, drainage, and cleanliness, to offer to cholera, should it be imported, no nidus or pabulum for its development. Should cholera arrive at any port in the United Kingdom, dependence is placed upon medical inspection, isolation of the sick, and disinfection.

In British ports, etc., the cholera sick are to be isolated in hospitals already prepared, and those suspected to be detained forty-eight hours; all healthy persons to be allowed to land, subject to notification of their address by the port sanitary authority to medical officer of health of proposed destination. The same order has recently been extended so as to include plague and yellow fever. International precautions against plague are regulated by the terms of the International Sanitary Convention of 1897, known as the Venice Convention.

If cholera breaks out during a voyage, the room in which the case occurs must not be used until thoroughly disinfected.

Medical Relief.—In this country cholera often begins in a comparatively tractable form of what is called 'premonitory diarrhœa.' It is deemed essential by Buchanan that where cholera has appeared, arrangements should be made for affording medical relief without delay to persons attacked, even slightly, with looseness of bowels.

Isolation.

It is absolutely necessary in diseases like cholera, typhus fever, and small-pox, that the patients should be immediately isolated in proper hospitals if they are at all fit to be moved. For other infectious diseases isolation at home may suffice, but unless it is complete (and this it very often is not) it is much better that the patients be removed to a hospital, the use of which by all

classes of the community should be encouraged, and with this view it is better that this provision be not made by the Poor Law authorities.

The Local Government Board have issued a memorandum (1892) on the subject of isolation in infectious disease hospitals, with some model diagrams and useful information on points of construction and management.

It is recommended that villages should combine to provide a hospital, or else each provide a four or six-roomed cottage, or arrange with cottage-holders not having children that they should receive and nurse, on occasion, patients requiring such accommodation. In towns or large districts permanent and special buildings are requisite and ought to be in readiness *before* infectious diseases threaten; if the Infectious Diseases (Notification) Act, 1889, is to be of use, the provision of hospitals is imperative. It is important also to provide a house for healthy members of a family where the patient cannot be moved, or while their own rooms are being disinfected.

In urban districts the hospital must not be more than two miles away (small-pox hospitals may be further if easily accessible), and should be placed outside towns.

In rural districts the hospital should not be more than four or five miles from the most populous place—*e.g.*, a market town.

Isolation Hospitals.

The Site.—A gentle slope is best, with dry soil, free circulation of air, abundant and wholesome water-supply, and facilities for drainage.

Acreage.—Twenty patients are allowed to each acre; an interval, 40 feet clear space, must everywhere be interposed between the boundary of the hospital site and every building (permanent and temporary) used for the reception of infected persons or things; the site must have an enclosing wall 6 feet 6 inches high, and should be provided with one or more gateways, with porters' lodges, where goods may be left and inquiries made.

Number of Beds.—There is always a probability that room will be wanted at the same time for two or more infectious diseases which have to be treated separately. The permanent provision to be made in a town should

consist of not less than four rooms in two separate pairs, each pair to receive the sufferers from one infectious disease—men and women, of course, separately. The number of cases for which permanent provision should be made must depend upon various considerations, among which are the size and the growth of the town, the lodgment and habits of its population, and the traffic of the town with other places ; for scarlet fever one bed per 1,000 of population is allowed, but this would not be sufficient in a town where a large number of children are congregated in schools.

Since improperly diagnosed cases may be sent into hospital, it is desirable to have a room or rooms where such cases may be isolated for a time.

An administrative block, with rooms for the staff, an isolation ward, laundry, mortuary, disinfecting room, and an ambulance must be provided.

For small-pox there must be a separate block, with its own kitchen and nurses' rooms, a laundry and ambulance, and a separate entrance from the rear of the grounds. It is preferable when practicable that the small-pox hospital should be entirely removed from the general isolation hospital.

Minimum Distance between Blocks.—If, of two buildings, one higher than the other, the distance between the two must be equal to the height of the higher ; if two buildings are the same height, then the distance must be one and a half times the height.

Below the *floors* concrete or asphalt must be laid down ; the space well ventilated ; the boards of the floor should fit into one another so as to leave no crevices, and should be polished.

The junction of the floor and walls should be round, and tops of doors should be cut slant, so that dust can be easily seen and removed.

Windows should be placed opposite one another, facing south of east and north of west ; by this means both sides are brought under the influence of the sun's rays, and direct exposure to the east wind is prevented. They should extend from 3 feet above the floor to within 6 inches from top of walls. One window should be between each two beds and one at the end of the room ;

it should be an ordinary sash-window with an upper flap. One square foot of window is to be provided for every 60 or 80 cubic feet of air in the ward.

Floor space per bed = 144 to 156 square feet.

Cubic space per bed = 2,000 to 2,500 cubic feet.

Height of wards = 14 feet ; all above that is not to be taken into account in calculating cubic space. *Longitudinal wall space per bed* = 8 feet.

Warming.—There should be one fireplace for every 25 or 30 feet of ward ; if only one is required it should be in the centre of a side wall ; if two, then one at each end.

The temperature of the wards is to be 60° F.

Hospitals are often also provided with ventilators below the heads of the beds, and the air is made to pass over hot-water pipes in winter. Key's combined system of warming and ventilation by the mechanical propulsion of screened, washed and warmed, or cool fresh air into every part of the building is being successfully used in several new hospitals.

Children are to have not more than a quarter less space than adults, but the full amount when possible.

Hospitals are now built on the pavilion or block plan, or in circular form. A *pavilion* consists of one, two, or three floors, each containing an oblong ward, rooms for convalescents, for nurses, etc. At the corners of the wards turrets are built to contain water-closet, bathing, and lavatory accommodation ; these are separated from the ward by short ventilated lobbies. The various pavilions are joined by means of terraces and corridors. In all hospitals the administrative department should occupy a separate block, in which also should be the rooms of the various officials, the kitchen, and dispensary.

Circular ward hospitals, as suggested by Mr. John Marshall, exist at Antwerp, Greenwich, and elsewhere. The diameter of a ward varies from 20 to 60 feet ; on the roof a day or sun room is sometimes constructed. The advantages claimed for this form are that—

Supervision is better.

Warming is more easily and more equably carried out ; the maximum of sunlight is obtained.

Ventilation is better.
Cleanliness is more easily secured.
The management is more economically conducted.

There is, however, a great waste of space in the centre of the ward. For infectious disease hospitals the pavilion form is the more suitable.

Small-pox Hospitals.—It has been suggested that in infectious disease hospitals, but especially with small-pox ones, the air should be extracted from the wards by a flue, so that the poison may be drawn through a furnace and thereby destroyed.

Disinfection.

In this connection a distinction is to be drawn between those agencies which have the power of completely destroying pathogenic micro-organisms (true disinfectants) and those which merely arrest or check microbic growth (antiseptics). Substances which merely mask the effluvia of putrescence (deodorants) have no valid claim to rank in either category.

Disinfecting Agents.—The agents employed in disinfection are—

1. Light.
2. Heat: (*a*) Dry heat; (*b*) boiling; (*c*) steam.
3. Chemical substances.

1. Light.—It has been proved that the direct rays of the sun, and even diffuse daylight, have a destructive influence upon micro-organisms, such action being due mainly to the actinic rays at the violet end of the spectrum, which generate hydrogen peroxide in the presence of air and moisture. Organisms which withstand considerable strength of chemical disinfectants succumb readily to light. Thus the exposure to a December sun for five hours has been found to inhibit the growth of anthrax, and unprotected organisms on clothing have been killed by exposure to direct sunlight. In Indian rivers the disinfecting power of actinic rays has been shown to be very considerable.

2. **Dry Heat.**—By thorough, complete drying, non-spore-bearing bacteria are destroyed, but this is not so with spores and spore-bearing microbes. Consequently, dry heat is not to be relied upon; moreover, no apparatus has been constructed by which a uniform temperature can be maintained in all parts.

Steam is employed for purposes of disinfection in (1) saturated, (2) superheated, or (3) in current form. Steam at any pressure is 'saturated' when it is at the boiling-point of water for that pressure. Thus the boiling-point of water at a pressure of 10 pounds on the square inch (in addition to the ordinary pressure of the atmosphere) is 239° F.; at a pressure of 20 pounds it is 261° F. If at any of those pressures steam be further heated it becomes 'superheated,' and is, in fact, a gas, and acts as one, communicating its heat slowly by conduction, whereas saturated steam rapidly raises the temperature of articles exposed to it, being condensed on coming in contact with the cooler objects. Thus the action of moisture as well as heat is brought to bear upon the microbe to be killed, whereas with superheated steam the high temperature prevents the deposit of moisture, except to a limited extent. An exposure of fifteen minutes to a temperature of 115° C. (239° F.) produced total disinfection, both inside and outside of a mattress, of the dried spores of symptomatic anthrax in a superheated steam apparatus. A lower temperature and pressure would be equally effective, but longer exposures must be given.

In constructing a disinfecting chamber the apparatus should be provided with two doors, one for admitting infected articles, the other opening into a separate compartment for withdrawal of the purified articles. Separate closed vans should be used for the conveyance of bedding, etc., to and from the disinfecting chamber.

3. **Chemical disinfectants** are employed in gaseous form, as liquids and as powders: some are germicides only, others may break up organic compounds, and thus act as deodorants; some evolve oxygen, and thereby neutralize the toxic products of germ life. Moreover, it is evident that free exposure to air or to oxidizing agents, as permanganate of potash, peroxide of hydrogen, ozone, etc., must be fatal to anaërobic organisms.

Spores and spore-bearing bacilli are more resistant to chemical disinfectants than non-spore-bearing bacilli and micrococci, while differences in this respect also exist among the various members of each class; thus the spores of *B. subtilis* and of *B. mesentericus* are more resistant than those of *B. anthracis*, and staphylococci than streptococci.

Mercury.—All the mercuric salts which can be kept stable and in solution have powerful germicidal properties; of these,

Corrosive Sublimate is a most trustworthy disinfectant to use, but it is poisonous; it corrodes iron and other metals, and is decomposed by contact with them; it unites with albumin to form an inert compound in animal and vegetable tissues (this is prevented to some extent by the presence of an acid).

For disinfecting excreta, clothing, floors, etc., the following solution is recommended by the Local Government Board: it is made with ½ ounce of corrosive sublimate, 1 fluid ounce of hydrochloric acid, to 3 gallons (a bucketful) of common water. It should be coloured with 5 grains of commercial aniline blue, with sulphate of copper or permanganate of potash to prevent accidents; it should be used, without further dilution, in wooden or earthenware house-tubs or buckets. This formula gives a solution of about 1 in 1,000.

A solution of 1 in 500 of corrosive sublimate (1 grain to 1 ounce of water) applied to any substance containing spores of even the most resistant organisms—*e.g.*, those of hay-bacillus, or of tubercle bacillus—sterilizes after an application lasting not more than a minute. A 1 in 1,000 solution sterilizes most spores though not all when acting from five to ten minutes, and a 1 in 5,000 solution kills all non-spore-bearing germs with certainty, even after a half to one minute's immersion.

Coal-tar products form the basis of many preparations recommended for disinfecting purposes. They owe any disinfectant property they possess to the amount of free cresols they may contain after the extraction of the absolute phenol (which is superior for antiseptic surgical purposes, but inferior as a disinfectant to the cresols). They are sold in various degrees of purity and

of strength. They are sparingly soluble in water, and various preparations are sold in which the solubility is increased by the addition of alkalies, soap, resins, etc. Probably a 1 in 1,000 solution of corrosive sublimate would be equal to a 5 per cent. solution of cresols.

All these coal-tar preparations are deoxidizing agents, and act as deodorants, but do not exercise any disinfectant action except upon articles with which they come in contact, as fluid, spray, or vapour.

Pure carbolic acid is extensively used as an antiseptic in surgery, 5 per cent. for the disinfection of instruments, etc., 2½ per cent. for contact with tissues.

Izal consists of an alkaline 50 per cent. emulsion of a clear reddish-brown liquid obtained as a by-product of coke ovens. It occupies a position chemically above the phenol group, and, from the experiments of Klein, has been shown to have at least equal disinfecting power with them. Diluted in the strength of 1 in 200 it destroyed in five minutes the vitality of the germs of cholera, diphtheria, typhoid fever, pneumonia, anthrax, and glanders.

Sulphurous acid acts also as a deoxidant. It is produced by burning sulphur moulded for the purpose into plates or candles, or by liberating liquid SO_2.

One pound of sulphur to each 1,000 cubic feet of the room to be treated is the quantity usually employed. This only gives a strength of about 1 per cent., which Dr. Alfred Carpenter long ago pointed out as being quite inadequate, especially after small-pox. Letheby recommended ½ ounce for 10 cubic feet. Koch's experiments show that the addition of moisture would increase the effect. He found that 1 part in 100 of air killed non-spore-bearing organisms, if dry, in twenty minutes; if moist, in one minute.

The tarnishing effect of SO_2 on gilt, on wall-papers, picture-frames, etc., constitutes a serious objection to its use for household disinfection.

Sulphuric acid, either alone or in combination with other compounds—as sulphates of iron, copper, or zinc—is a powerful disinfectant. A cheap and effective disinfectant may be made by mixing 16 ounces of crude carbolic acid and 2 ounces of commercial sulphuric acid (oil of vitriol) with 3 gallons of water.

Anhydrous ferrous sulphate may be employed for deodorizing collections of filth.

Chlorine is an effective disinfectant, but acts best in the presence of moisture, liberating oxygen from the water. The gas may be evolved by gently heating a mixture of 4 parts common salt and 1 part of manganese dioxide with 2 parts by weight of sulphuric acid and 2 of water; or of 4 parts by weight of strong hydrochloric acid with 1 part of manganese dioxide.

Chloride of lime applied in a solution of 1 in 100 is of great value for washing walls or surfaces requiring disinfection, and also as powder for the disinfection of excreta. It should contain at least 25 per cent. available chlorine.

Nitrous acid (NO_2) can be evolved from copper filings by the action of dilute nitric acid. It oxidizes organic matter, being thereby reduced to NO, which at once absorbs oxygen from the air again and continues the process. It has been recommended for dead-houses. *Iodine*, *bromine*, *euchlorine*, etc., have been suggested, but they are too expensive for general use.

Permanganate of potash is a good deodorant and a true disinfectant to some extent, but its action is much weakened if the infective matter is mixed with a quantity of other organic matter. It is non-poisonous, but stains clothing, etc. It may be used for street watering; for this purpose manganate of soda, 1 pound; sulphuric acid, $\frac{1}{2}$ pint, and water, 1 gallon, may be added to every 100 gallons of water. Hankin found that the addition of permanganate to wells contaminated with cholera caused the microbe to disappear from the water; but the natives of India have a great objection to water thus treated, and 'pinking' the wells often has the effect of making them resort in preference to natural streams which may be highly polluted, and thus the remedy may actually tend to an increase of the disease.

Peroxide of hydrogen (H_2O_2) is a powerful germicide and deodorant, liberating nascent oxygen. Certain essential oils, as turpentine, when exposed to the air absorb oxygen, producing an organic peroxide of camphor, which remains dissolved in the body of the oil and communicates thereto properties resembling peroxide of hydrogen.

If the oxidized oil be treated with water an aqueous solution of H_2O_2 results (Kingzett).

Sanitas is a good example of this class of disinfectant. A gallon of sanitas oil has an oxidizing power equal to 10 gallons of oxygen, while the fluid is capable of liberating two or three times its own volume of nascent oxygen.

Being non-poisonous and not staining, this preparation is well adapted for use in cases of fever, for soaking linen in, for spraying upon walls, floors, in the air, etc. It is also useful for street watering, especially in narrow streets and courts and on wood pavements.

As regards those poisonous ferments produced by various organisms, chemical research into their nature has not as yet given us means of destruction, but it is possible their poisonous properties may be removed by further processes of oxidation, as tyrotoxine, which is believed to be identical with diazobenzol (V. C. Vaughan), is decomposed upon exposure to the air.

Formic Aldehyde (CH_2O) has recently been brought forward as a disinfectant in vapour and in solution. It may be produced in vapour by the incomplete combustion of wood-spirit in a spirit lamp, the wick of which is surrounded by a projecting spiral of platinum wire. The wick is first lighted, and after a few moments is extinguished, leaving the platinum red hot; incomplete combustion then goes on, the heat produced by the oxidation of the vapour serving to keep up the temperature of the wire. It is free from corrosive action upon metals, furniture, and fabrics, but has considerable penetrating power.

Vapour of a strength of 1 per 1,500 has been shown to be capable of killing *B. typhosus* and *B. coli communis* in ten minutes. Its solution (formalin) is now extensively used by sanitary authorities for house disinfection by spraying. Formalin contains 40 per cent. of formic aldehyde, and is effective for spraying in a solution of 2 to 4 per cent. in hot water.

Powders.—Disinfectant substances may be added to absorptive bases, as kaolin, siliceous residues, saw-dust, peat-powder, or lime. Such disinfectant powders are often coloured pink with rosanilin.

Peat has a distinct antiseptic value, apart from the

moisture contained in it. It may be applied to deodorize fæcal masses, as the contents of cesspools. In the Goux system peat is used for the lining of sanitary tubs, with or without the addition of sulphuric acid.

General Directions.

If a patient suffering from an infectious disease has to be treated at home, the following rules (based on those recommended by the Society of Medical Officers of Health) should be observed :

1. The patient shall be at once separated from the other inmates of the house, and, if possible, placed in a room at the top of the house, and have that floor devoted to him and his attendant.

2. All bed-curtains and other hangings, carpets, and all articles of dress and the like in wardrobes and cupboards, and all unnecessary articles of furniture, should be removed.

3. The room should be well ventilated, windows should be kept partly open (the patient being protected from draughts or chance of a chill by a screen when necessary), communication with the chimney free, and, if the weather or size of the room permit, the fire burning. The floor should be sprinked with disinfectant fluid and cleansed daily.

4. The door should be kept closed, and a sheet, kept wet with a disinfectant fluid, hung outside it so as to cover every crevice.

5. Everything that passes from the patient (sputum, vomit, urine, fæces) should be received in vessels containing a disinfectant ; and an additional quantity of the disinfectant should be added to the vessel *before* removing it from the room and emptying it into the closet. All superabundant food or drink, and all scraps and refuse, should be mixed with disinfectant, and under no circumstances partaken of by other persons ; it is best to burn as much as possible.

6. Pieces of rag used for wiping discharges from the nose or mouth should be burnt immediately after use.

7. All cups, glasses, spoons, or such like articles used in the sick room, should be placed in some disinfectant

solution before leaving it, and subsequently washed in hot water.

8. All bed and body linen after use should at once, and before leaving the room, be put into a disinfectant solution, and after remaining in this at least an hour, may be washed. When the grosser dirt has been removed by rinsing in water, the articles may be boiled—if this were done first the albumin would be coagulated and the clothes stained.

9. The patient's person and bed should be kept scrupulously clean, and when, during the progress of the disease, scales or crusts form upon the skin their diffusion should be prevented by smearing the surface of the body from head to foot daily with olive oil to which some antiseptic volatile oil, as camphor, has been added. Sanitas may be added to the water used for washing.

10. Nurses in attendance should, if possible, be such as have already had their patient's disease ; their dresses should be of washable material; they should keep their hands clean, and should as far as possible avoid inhaling the patient's breath, or other emanations from his person or discharges. They should remain with the patient, or—if compelled to leave the room—leave it under proper precautions, and under no circumstances mix with other members of the household.

11. Visitors should not be allowed, or, if allowed, should conform to the conditions required of the ordinary attendant.

12. In cases of small-pox, members of the household should be re-vaccinated.

13. The patient must not be allowed to mix with his family until all specific phenomena of disease have disappeared, and until he has been well purified by the use of warm baths containing a disinfectant. Clothes used during the time of illness or in any way exposed to infection must not be worn again or put away in drawers or wardrobes until they have been properly disinfected by steam.

14. The house in which the patient suffering from infectious disease resides should, during his illness, be well ventilated and kept very clean ; all sinks, water-closets, traps, and gullies, should be in good order, and have some disinfectant solution poured into them daily ;

dust-bins should be regularly emptied, and all offensive accumulations removed. All water-butts and cisterns should be kept clean and well covered. The greatest possible care should be taken to prevent contamination of the drinking-water.

15. Should death occur, the body should as soon as possible be wrapped in a sheet saturated with a disinfectant and be placed in a coffin, which should be filled up with some absorptive powder, as sanitas sawdust, and the lid at once screwed down; the funeral should take place at an early date. Mourners should not meet in the room in which the death took place. If the body is a danger to health it may be removed to a mortuary. (See also Infectious Diseases Prevention Act, 1890.)

16. When the sickness has terminated, the sick-room and its contents should be disinfected and cleansed.

Bedding, blankets, carpets and such like, which cannot well be disinfected at home, must be disinfected by *steam*. Where articles have been soiled with albuminous matter, the heat will cause coagulation and a permanent stain, unless the soiled parts have been previously washed in cold water.

If the bedding or other articles are very filthy or dilapidated they should be destroyed by fire, and compensation given for them (Section 121, Public Health Act). Leather and letters should be exposed to dry heat only.

After the room has been prepared by the removal of persons and of such articles as are best disinfected by steam, and by the closure of windows, chimney outlet, and all crevices, it may be purified by the use of sulphurous acid, chlorine, or formic aldehyde, as above. After the room has been closed for twelve hours, it should be thrown open to the light and air and thoroughly ventilated; all wall-paper, which should have been previously moistened by washing or by spray, should be stripped from the walls and burnt; all woodwork and furniture should be washed over with soap and hot water.

The ceilings and walls must be thoroughly washed and lime-whited or re-papered. After cases of small-pox or diseases of special virulence it will be well, before burning sulphur or the like, to spray the walls, woodwork, and floor with a solution of corrosive sublimate (1 in 1,000).

CHAPTER XI.

DISPOSAL OF THE DEAD.

Mortuaries.—'When the body of a person who has died from any infectious disease is kept in an apartment wherein persons reside or sleep, or when any corpse in such a condition as to endanger the health of the inmates of the same house or room is retained therein, a magistrate is empowered, on a certificate signed by a medical man, to order the removal of the body, at the cost of the local authority, to any mortuary provided by it.' It is, therefore, desirable that all local authorities should avail themselves of the power given them in the Public Health Act, 1875, to erect mortuaries in their districts (see Model By-laws).

If a dead body be exposed to a temperature of 60° F., in three days it will begin to putrefy and give off offensive gases. If a body must be kept longer than that time it should be in a well-ventilated room, and should be approached as little as possible. The presence of aerial disinfectants is desirable. As a result of inhaling the effluvia from dead bodies the writer has known several cases of severe illness, as pulmonary abscess, etc.

A post-mortem room is often included within a mortuary; but although this would appear to be an appropriate situation for it, the legislature has enacted that a post-mortem room may be provided, but not at a mortuary or workhouse. The reason for this prohibition is evidently to remove any suspicion that the fact of taking a body to a mortuary necessitated dissection, or pauperized those availing themselves of it for their relatives.

Mortuaries are provided in connection with hospitals and cemeteries, while others should be provided in central positions in districts for the reception of bodies to await identification and the coroner's inquest. It has been computed that for every 50,000 of the population of any town a mortuary should be provided.

Separate provision should be made for the reception of bodies of persons who have been suffering from infectious

disease. It is desirable also that public mortuaries be near the coroner's court-room.

As to the ultimate disposal of dead bodies, two methods are at present in use—viz., burial and cremation.

Burial.—When burial is performed in a perishable coffin (the 'earth to earth' system advocated by Seymour Haden) in a suitable soil, the body is reduced to an elemental condition in from three to six years.

Cemeteries.

Dr. Parsons, in a Local Government Board memorandum, has embodied what he considers the sanitary requirements of cemeteries: The soil should be of an open, porous nature, with numerous close interstices, through which air and moisture may pass, in a finely divided state, freely in every direction. It should be free from water or hard rock to a depth of at least 8 feet. If it has to be drained, it must be raised above the drainage level of the locality. Loam and sand with vegetable remains make the best soil; clay and loose stones the worst. The site to be chosen for a cemetery should be in a neighbourhood in which building is not likely to take place, as the erection of houses interferes with the free play of air around and over it; a cemetery must not be constructed within 200 yards of any dwelling-house without consent of the owner or occupier. It should stand exposed to north or north-east winds. Ground-air and ground-water are both liable to be contaminated; care must, therefore, be taken to prevent wells and streams and foundations and cellars of houses being polluted. It would be well if a cemetery could be placed at a lower level than the town, so that the water which drains from it may not flow under the town.

When bodies are placed in vaults and in lead and wooden coffins decay is merely postponed, and, sooner or later, the offensive products must find means of escape; hence the objection to intramural interments. A strip of ground 15 to 30 feet wide all round must be kept free from interments on the interior of the boundary fence. This strip would afford room for a gravel or asphalt walk, and next the fence should be planted rapidly-

growing shrubs and plants, so that decomposing matters percolating to the exterior of the cemetery may be arrested and assimilated by them.

Space.—With regard to the amount of land necessary, the usually estimated minimum is a quarter of an acre of land for every 1,000 of the population of the community. The regulations issued from the Home Office in 1863 for grounds under the Burial Acts require that—

The grave-spaces for persons above twelve years of age shall be at least 9 feet by 4 feet (4 square yards); under twelve years of age 6 feet by 3 feet, or $4\frac{1}{2}$ feet by 4 feet (2 square yards). There must be at least a foot between each grave.

No unwalled grave shall be reopened within fourteen years after the burial of a person above twelve years of age, or within eight years under twelve, unless to bury another member of the same family, in which case a layer of earth not less than 1 foot thick shall be left undisturbed above the previously buried coffin.

No coffin shall be buried in any unwalled grave within 4 feet of the surface of the ground, unless it contains the body of a child under twelve years of age, when it shall not be less than 3 feet below the level.

To the many objections to burial must be added the danger that accrues from the bodies of persons who have died of an infectious disease. It is possible that pathogenic microbes are destroyed by germs of putrefaction, but this destruction is not complete, for Pasteur has shown that spores may resist putrefactive action for years; and, as the home of many pathogenic microbes is the soil, no better arrangement could be desired for their propagation. As pointed out by Darwin, earth-worms play an important part in propagating disease by bringing up to the surface of the ground specific germs which have been buried as deep as 7 feet.

Very few bacilli are found at a depth greater than $1\frac{1}{2}$ metres. If it were not for the regulations of the Home Office shallow burial within the depth occupied by nitrifying bacteria would promote resolution quicker than deep burial. These considerations, coupled with the fact that land used for a cemetery is a dead loss to the country, are producing a feeling that **cremation** is the safest and best

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way to dispose of the dead. The body is then resolved as speedily and as inoffensively as possible into its constituent elements. Especially is cremation suitable for the bodies of persons who have died from infectious disease. The chief objection to cremation is that crime might be hidden, as poisons would be dispelled by the heat, but this may readily be avoided under a proper system of death certification. An Act to permit sanitary authorities to erect crematoria was passed in 1902.

Disused burial-grounds may be laid out as recreation grounds by local authorities, under the Open Spaces Acts, 1881 and 1887, but not be built over.

CHAPTER XII.

DUTIES OF THE MEDICAL OFFICER OF HEALTH.

THE duties of the medical officer of health can be learned only by practical experience; but, for his guidance, the Local Government Board has issued an order defining what they are. The following embodies the principal clauses:

He shall inform himself as far as practicable respecting all influences affecting or threatening to affect injuriously the public health within the district.

He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

He shall by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

He shall be prepared to advise the local authority on all matters affecting the health of the district, and on all sanitary points involved in the action of the local authority; and in cases requiring it, he shall certify, for the guidance of the local authority or of the justices, as to any matter

in respect of which the certificate of a medical officer of health or a medical practitioner is required as the basis or in aid of sanitary action.

On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, *he shall visit the spot without delay and inquire into* the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and, so far as he may be lawfully authorized, assist in the execution of the same.

The meaning of the above article has been further explained as follows :

'It appears to the Board to be undesirable that the medical officer of health should in general undertake a personal diagnosis of the notified cases in order to test the accuracy of the certificates. In some cases—as where there is reason to doubt the good faith of the certifier, or where the disease is one which in itself, or owing to the attendant circumstance threatens exceptional danger to the community—it may be desirable that the medical officer should make a personal diagnosis, but it must be remembered that this can only be done with the consent of the patient, or those having charge of the patient, and that the medical practitioner in charge of the case should always be communicated with, and his co-operation secured, if possible.'

Thus, should a case of small-pox, typhus fever, plague, or cholera occur, the medical officer should promptly visit the case, and in the case of the two latter should at once communicate with the central authorities (Local Government Board and County Council).

Subject to the instructions of the local authority, he shall direct or superintend the work of the inspectors of nuisances in the way and to the extent that the local authority shall approve, and on receiving information from any inspector of nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps authorized

by the statutes in that behalf as the circumstances of the case may justify and require.

In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the local authority, he shall himself inspect and examine any animal intended for the food of man which is exposed for sale, or deposited in any place for the purpose of sale or of preparation for sale, and any articles, whether solid or liquid, intended for the food of man, and sold or exposed for sale, or deposited in any place for the purpose of sale or of preparation for sale. If such animal or article appears to him to be diseased or unsound, or unwholesome, or unfit for the food of man, he shall seize and carry away the same himself, or by an assistant, in order to have the same dealt with by a justice according to the provisions of the statutes applicable to the case.

He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

He shall from time to time inspect any bakehouses which are workshops, and are situate within the district, and he shall thereupon report to the sanitary authority whether any steps are necessary to be taken for the purpose of enforcing as respects such bakehouses the provisions of Acts applying thereto.

He shall report in writing to the authority from time to time (weekly, fortnightly, or as directed) on all deaths (classified according to age, cause, and locality), and, so far as practicable, on all important sickness in the district; on such newly-observed unwholesome conditions as the authority can abate, and on the completion, progress, or neglect of improvement in matters previously reported on.

(The medical officer of health is supplied with weekly returns from the registrar of births and deaths, with a list of new cases coming under treatment by the Poor Law medical officer, to be furnished by the clerk, and with reports of any dangerous sickness coming under the notice of the Poor Law medical officer.)

He shall make the examinations of buildings in the district, the owners of which claim exemption from House Duty under Section 26 of the Customs and Inland Revenue

Act, 1890, and grant certificates under that Act and any amending Act in accordance with such examinations.

He shall also prepare an annual report, to be made to the end of December in each year, comprising a summary of the action taken, or which he has advised the local authority to take, during the year for preventing the spread of disease, and an account of the sanitary state of his district generally at the end of the year. The report shall also contain an account of the inquiries which he has made as to conditions injurious or dangerous to health existing in his district, and of the proceedings in which he has taken part or advised under any statute, so far as such proceedings relate to those conditions; and also an account of the supervision exercised by him, or on his advice, for sanitary purposes over places and houses that the local authority has power to regulate, with the nature and results of any proceedings which may have been so required and taken in respect of the same during the year. It shall also record the action taken by him, or on his advice, during the year, in regard to offensive trades, to factories and workshops, and dairies. The report shall also contain tabular statements (on forms to be supplied) of the sickness and mortality within the district, classified according to diseases, ages, and localities.

He shall give immediate information to the Local Government Board and to the County Council of any outbreak of dangerous epidemic disease within the district. He shall also transmit to them a copy of each annual and of any special report made by him.

In drawing up the annual report, it is necessary that the population of the district should be ascertained as correctly as possible. As the census is taken only once in ten years, the population for each year during the decade must be estimated. The Registrar-General assumes that the *rate of increase*, or of decrease, which prevailed between the last two enumerations will continue during the next ten years. For small places it may be sufficient to add for each year one-tenth of the *actual increase* shown at the last census; but in large towns this would lead to a considerable amount of error: the annual increase may be due to immigrations, as well as to the excess of births over deaths and by the former method

no notice would be paid to the increase of population which would ensue from the annual increment.

The census is taken at the end of the first quarter of the year, but populations are estimated to the middle of the year; an additional quarter has therefore to be included. Thus, to estimate the population of a place for any given year in the present decade, the logarithms of the two last census returns are to be found, and the lesser subtracted from the greater; this will give the logarithm of the rate of increase for the last decade; a tenth of this will be the logarithm of the annual rate of increase, which, multiplied by the number of years since the last census, plus a quarter, and added to the last *enumerated* population, gives the *estimated* population for the year in question; or, to put it as a formula:

Let a be the population in 1871
,, b ,, ,, ,, 1881
,, D be the difference between a and b,
and $\frac{D}{10}$ = the annual rate of increase.

Then, assuming that the population is increasing or decreasing in the same ratio in this decade as in the last, the logarithm of the population in the middle of 1890

$$= \log. b + 9\tfrac{1}{4}\left(\frac{\log. D}{10}\right).$$

Or, the annual rate of increase having been found by logarithms, and the estimated population for the year immediately preceding being known, the population for the current year may be obtained by multiplying those two factors together.

It must be kept in mind that there are often in operation causes known to the local medical officer which would render calculations such as the above incomplete and fallacious. Such causes as demolition of property, opening of common lodging-houses, lying-in and other hospitals, workhouses, immigration, emigration, etc., should be recognised by the medical officer of health, and the necessary corrections made, else the death and other rates will appear higher or lower than actually is the case.

The number of births per annum is sometimes taken as a basis of calculation, as is also the number of inhabited houses in a district; but this requires discrimination, as the class of house may vary. The Education Department estimates the number of children between three and thirteen at one-sixth of the whole population.

It has been pointed out that the estimated population of sub-districts added together may differ from the estimated population of the whole district, as there may be different rates of increase.

By the following formula, suggested by Dr. Louis C. Parkes, the estimated sub-district populations may be so corrected as practically to agree with the estimated population of the whole district:

If P be the estimated population of the whole district for 1892, and p the census population in 1891, and if P_1, P_2, P_3, and p_1, p_2, p_3, stand for corresponding populations in the sub-districts, then

$$P = \frac{p_1}{p} P_1 + \frac{p_2}{p} P_2 + \frac{p_3}{p} P_3.$$

Statistical inquiries applied to health relate to:

1. *The proportion of marriages to population.*
2. *The proportion of births to population.*
3. *The relative number of live and still-born, of premature and full-grown, children.*
4. *The number of children dying in the first year*, with sub-groups of sex and months. Two great periods of mortality in the first year of life occur, one in the first week, the other about the time of weaning.
5. *The amount of sickness to population.*

This estimation may be partly estimated from the books of the Poor Law Medical Officer.

6. *The amount of mortality in a population*, grouped according to age, sex, disease, etc. Both the birth-rate and death-rate are calculated per 1,000 persons living, and may be computed from the weekly, monthly, quarterly or other returns, by a proportion sum:

Estimated population : 1,000 : : total births for year : x.
or......deaths......

It is necessary to remember that an exact or natural year contains 365·24226 (say, 365·25) days, and 52·17747 weeks. To obtain the weekly rate, multiply the number of births (or deaths) for the week by 1,000 and by 52·17747, and divide by the population; and similarly for other periods. Before calculating mortality statistics, it is necessary to deduct deaths in hospitals, etc., of persons whose previous residences were not in the same districts as the hospitals, and to add deaths taking place in outlying institutions of persons who previously had lived in the district for which the calculation is being made. Such information is obtained from the death register. The weekly averages may be compared with 'corrected averages': these are the average weekly deaths for the previous ten years, raised so as to allow for the increase in population.

7. *The mortality from zymotic diseases.*

8. *The mortality as affected by occupation.*

Conclusions which may be drawn from the statistics supplied by medical officers of health: Death-rates calculated for very short periods are liable to accidental fluctuations, and are not of great value, as also those calculated on small populations,* or on a limited number of cases; numerous factors must be taken into account before saying that a death-rate is good or bad, and before instituting comparisons between the death-rates of different places. Regard must be had to the social conditions and occupations of the people, and especially to the *age and sex distribution:* thus among the poorer classes the death-rate of children is much higher than that of the better-off classes; or, again, as the average duration of life among women is greater than amongst men, the death-rate will probably be lower in a place where women predominate than where the opposite prevails; so, again, health resorts may have their death-rates increased or diminished by the class of people frequenting them. In order to better compare rates, the Registrar-General at the census periods makes up a table showing the mean annual death-rate for each sex and age period for the whole country (England and Wales) for the past ten

* Error diminishes as the square root of the number of observations.

years, and provides a series of factors by which the recorded death-rates of the principal towns can be each multiplied so as to make them comparable with that of England and Wales. By the use of these factors the recorded death-rate of any town or district for which a factor is supplied can be raised or lowered to what it would be if the age and sex distribution of that particular town were the same as that of England and Wales generally. The rate thus obtained is called the *corrected death-rate.* The factor employed is practically the expression of the ratio which the recorded death-rate bears to an empirical *standard death-rate* calculated on the hypothesis that deaths at each age-period were at the same rate as in England and Wales generally.

The mortality of towns as compared with that of the entire country is, with but few exceptions, much greater than would be concluded from the recorded general death-rates. The towns contain, as a rule, a much smaller proportion of aged persons and a much higher proportion of persons in the prime of life than does the country at large, and though these advantages are somewhat counterbalanced by an excess in the proportion of children, they are so to a limited extent only.

The *comparative mortality figure* for any given town is obtained by comparing its corrected death-rate with the death-rate at all ages in England and Wales taken as 1,000.

In comparing death-rates of various *occupations* care must be taken to obtain exact data, and to work out the statistics for each age-group.

A *high birth-rate* need not necessarily be combined with a high death-rate, as was argued by Dr. Letheby ; it is upon age distribution that both birth-rate and death-rate depend. The conclusion to be drawn from a high birth-rate is that the population contains a high percentage of young adults (whose mortality-rate is low), and consequently a low percentage of elderly people (with a high death-rate). Unfortunately, however, from improper feeding, maternal neglect, and insanitary conditions generally, a high birth-rate is often accompanied by a high death-rate. The susceptibility of young children to diseases, especially those of zymotic origin, increases the

death-rate, and, as there are fewer deaths among persons between the ages of fifteen and fifty-five than in those above or below these ages, the larger the proportion of that class in a population, the lower will be the death-rate. The causes, however, it should be noted, come entirely under the class known as 'preventable.'

A low birth-rate tends at first to lower the death-rate, but after a lapse of years, as the number of persons in the more central groups decreases, the death-rate will probably rise again.

Infantile Death-rate.—It is usual to state the deaths of children under one year of age as so many per 1,000 registered births, rather than per 1,000 of estimated population, as the former is more likely to be correct; thus the mortality of infants under one year of age in England and Wales was calculated for 1888 to be 145 per 1,000 of the estimated population at that age, while per 1,000 births registered in 1888 it was only 137.

For the purpose of more exact comparison between one and another district, it is suggested that, in view of the different age and sex distribution, the births should be considered in relation to the number of women at the child-bearing age. For practical purposes, this may be reckoned as including the ages fifteen to forty-five years. It is also desirable to distinguish the illegitimate births; about 4·2 per cent. of the total births fall under this category.

The average annual rate during the ten years (1879-88) was equal to 141 per 1,000 registered births: it varied in the large towns from 139 to over 200 (in Preston and Leicester), while in the chain-making district of Cradley Heath it is reported to have been as much as 500. In the third quarters of those years (when infantile diarrhœa was prevalent) the average was 156 per 1,000 in England and Wales; 206 in the large towns. Under 1 year of age, males die in the proportion of 54 to 49 females. The average death-rate per 1,000 living under 5 years of age is about 63 for both sexes, the rate being 68 for male, 58 for female children. One quarter of these deaths is due to the zymotic class, the rest to diseases of the head and chest, abdominal tubercle, and diarrhœa. In 1898 the infantile death-rate reached 160.

The causes conducing to the large mortality in the earlier years of life are ascribed by Dr. George Wilson to:

1. Early marriages and weakly parents.
2. Hereditary disease.
3. Insanitary surroundings and unfavourable social conditions.
4. Improper feeding.
5. Insufficient clothing and exposure.
6. Infant life assurance.

From 5 to 10 years of age the mortality is 6·4 per 1,000 living at these ages; from 10 to 15 years of age it is 3·7 per 1,000. After 15 years of age the number of deaths in each 5-yearly period gradually increases; between 55 and 65, 31·5 die; between 65 and 75, 64·9; and over 75, 161·6 per 1,000 living at each of those groups of ages.

Zymotic Death-rates.—The death-rate from individual zymotic diseases should always be carefully reviewed, with the aim of determining the relation to defective sanitary arrangements; for the incidence of measles, whooping-cough, or scarlet fever bears a different interpretation to a high or frequently recurring death-rate from enteric fever or diphtheria. The latter shows unmistakably that the sanitary arrangements are defective, while the former indicates a failure on the part of the sanitary authority to control the spread of the disease by such means as isolation, disinfection, etc.

The zymotic death-rate refers only to the seven principal diseases of this class—viz., small-pox, scarlet fever, measles, diphtheria, whooping-cough, diarrhœa, and fever (including therein enteric, typhus, and simple continued).

Especial attention should be paid to the mortality from diseases of tubercular origin. The existence of such is indicative of the conditions under which a population work and live—dampness of soil, defective ventilation, back-to-back houses, and such like, are usual concomitants of a high phthisis rate.

The zymotic death-rate has of late years shown a steady tendency to fall. In 1901 it was 2·05 per 1,000 living for England and Wales.

The average annual death-rate for the ten years from

the beginning of 1881 to the end of 1890 in England and Wales was:

All causes	19·08
Zymotic diseases	2·36

In 1894 both birth and death rates throughout the country were low, but the following table shows the relative position of urban and rural communities:

	Birth-rate.		Death-rate.
England and Wales ...	29·6	...	16·59
Thirty-three great towns	30·7	...	19·59
England and Wales, less the thirty-three towns	29·9	...	15·54
Sixty-seven other large towns...	30·5	...	16·00

Farr held that a sustained general death-rate of over 17 per 1,000 implies unfavourable sanitary conditions.

On the other hand, exceptionally low death-rates should be looked on with some suspicion.

Dr. A. Ransome describes a rate of 10 per 1,000 as 'an impossible death-rate,' one which could not possibly occur in a population normally constituted, and the statistics of which are not vitiated by the disturbing influence of migration.

A mortality-rate of 12 means an average age at death of 83. Such low rates are produced in the suburbs of a town by the removal of servants during illness, in the country by the non-inclusion of deaths of residents in hospitals, Poor-Law institutions, asylums, etc.

Birth-rate.—For the ten years ending ending 1893, the average birth-rate of England and Wales was 31·6 per 1,000 persons living, having gradually decreased since 1876, when the highest rate (36·3) for the whole country was recorded; that of the year 1894 (29·6) being the lowest. One hundred and five males are born to every 100 females; the death-rate of male children is, however, higher than that of female.

The marriage-rate has also been declining of late years. For many years it was between 16 and 17 per 1,000 living, but from 1881 to 1890 the average annual rate was only 14·9.

Life Tables.—Tables have been constructed by Farr and Ogle for England and Wales, which show the expectation of life at any age, and what is the average length of time a person of any age may be expected to live, the last table being for 1871-80.

The data on which a life table is formed are the number and sex of the living at each year of life, and the number and sex of those dying at each year.

The mean age at death of a population is the sum of the ages at death divided by the deaths. This gives no information as to the health or sanitary condition of a people, as great infant mortality may reduce the age, though the health of the adults may be good. The mean age at death in England is 42 for males and 45 for females.

Table, after Dr. Tatham, showing the Annual Mortality at all Ages per 1,000 Persons living during each Five-year Period of the Latter Half of the Last Century, and the Mortality amongst Infants under 1 Year of Age per 1,000 Children born in each Similar Period.

Years included.	Deaths at all Ages per 1,000 living.	Deaths under One Year per 1,000 Births.
1851–1855	22·7	157
1856–1860	21·8	152
1861–1865	22·6	151
1865–1870	22·4	157
1870–1875	22·0	153
	Average 22·3	Average 154
1876–1880	20·8	144
1881–1885	19·4	139
1886–1890	18·9	145
1891–1895	18·7	151
1896–1900	17·7	156
	Average 19·1	Average 147

APPENDIX.

WATER-GAS.

A LARGE proportion of this gas is now mixed with ordinary coal-gas by many companies, and constitutes a grave danger by reason of the high proportion (25 to 40 per cent.) of carbon monoxide which it contains. An admixture of water-gas with coal-gas to the extent of 12 per cent. has been laid down by a Departmental Committee as a permissible quantity.

MILK.

In August, 1901, the Board of Agriculture, in exercise of the powers conferred on them by Section 4 of the Sale of Food and Drugs Act, 1899, made the following regulations :

1. Where a sample of milk (not being milk sold as skimmed, or separated, or condensed milk) contains less than 3 per cent. of milk-fat, it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk-fat, or the addition thereto of water.

2. Where a sample of milk (not being milk sold as skimmed, or separated, or condensed milk) contains not less than 8·5 per cent. of milk solids other than milk-fat, it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk solids other than milk-fat, or the addition thereto of water.

A new feature in milk analysis has been the sampling of skimmed or separated milk, and in connection with this the Board have issued the following regulation :

SKIMMED OR SEPARATED MILK.

3. Where a sample of skimmed or separated milk (not being condensed milk) contains less than 9 per cent. of milk solids, it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk solids other than milk-fat, or the addition thereto of water.

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